The Pleistocene Solent River and its major tributaries: reinterpreting the fluvial terrace stratigraphy as a framework for the Palaeolithic archaeology of the Solent region

Marcus Hatch

Queen Mary, University of London

December 2013

Submitted in partial fulfilment of the requirements of the Degree of Doctor of Philosophy

I, Marcus Hatch, confirm that the research included within this thesis is my own work or that where it has been carried out in collaboration with, or supported by others, that this is duly acknowledged below and my contribution indicated. Previously published material is also acknowledged below.

I attest that I have exercised reasonable care to ensure that the work is original, and does not to the best of my knowledge break any UK law, infringe any third party's copyright or other Intellectual Property Right, or contain any confidential material.

I accept that the College has the right to use plagiarism detection software to check the electronic version of the thesis.

I confirm that this thesis has not been previously submitted for the award of a degree by this or any other university.

The copyright of this thesis rests with the author and no quotation from it or information derived from it may be published without the prior written consent of the author.

Signature:
Date:

Abstract

Despite recent interpretations of the fluvial terrace stratigraphies of the Palaeo-Solent River and its major tributaries, the River Test and River Stour, fundamental issues concerning correlation both within and between key parts of the system remain. Addressing these issues is important to provide a secure stratigraphic framework for the Palaeolithic archaeological record of the region. Disagreement centres on contrasting approaches to the construction of long profile projections of terrace sediments and landforms, and on alternative interpretations of limited stratigraphic and topographic data. During the study extensive fieldwork has been carried out in the region, comprising ground penetrating radar surveys, coastal section recording and re-excavation of key sites. In addition, an examination of the available borehole archive held by the British Geological Survey has provided a substantial body of new data on which a reanalysis of the terrace stratigraphy is based.

During fieldwork 26 samples of suitable fluvial sediments were also taken for optically stimulated luminescence (OSL) dating. A rigorous OSL analysis and test program applied to these samples highlights a number of issues inherent in dating sediments from Middle Pleistocene fluvial environments. It also raises potential issues with previously published OSL dates from similar environments, including in the Solent Region, which typically have not received such detailed test procedures. Despite the problems encountered age estimates have been produced for a number of terraces in the Solent River.

The enhanced stratigraphic dataset produced by this study is used to critique published stratigraphic models of the Solent system and to create alternatives. A reinterpretation of the terrace stratigraphies of the Solent River, the River Test and River Stour is presented and revised correlations between the three parts of the Solent system are proposed. These provide a new stratigraphic framework for the Palaeolithic archaeology of the Solent River system.

Acknowledgments

The completion of this thesis would not have been possible without the support, guidance and assistance of a number of people. My supervisory team consisting of Simon Lewis (Queen Mary, University of London), Nick Ashton (The British Museum), Becky Briant (Birkbeck, University of London) and Sven Lukas (Queen Mary, University of London) provided a never ending source of inspiration and insightful feedback throughout my studies, and above all demonstrated patience beyond the call of duty. Thanks for everything. Rob Davies (University of Reading) has collaborated on the project, producing a thesis on the Palaeolithic archaeology of the Solent River system. He was an invaluable colleague during fieldwork, assisting with excavations, ground penetrating radar surveys and coastal section recording, and provided a trusted sounding board throughout this project.

I would like to thank everyone at the Department of Geography at QM for the friendly and collaborative atmosphere that contributed to the completion of this work. In particular Laboratory manager Simon Dobinson was always ready with the solution to any technical problem encountered, or a least a sarcastic comment to summarise the predicament. Thanks to everyone in Room 104 over the years, especially Amanda Ferguson, Clare Boston, Harold Lovell and Ginny Benardout, for laughs, drinks and keeping the glacial chat to a minimum. I am grateful for the assistance of the British Geological Survey in allowing access to their borehole data archive at Keyworth, Nottingham. I am also grateful to Peter Wilkins (Kimbridge on the Test) for permission to access fieldwork locations at Dunbridge, and to Graeme Wilkins (Hampshire County Council) and Andrew Graham (tenant farmer) for access to sites at Warsash.

Most importantly I thank my family for being my family. I love you all.

The study was funded by a Collaborative Doctoral Award from the Arts and Humanities Research Council. Additional fieldwork costs were funded by grants awarded from the Queen Mary, University of London Central Research Fund and the Quaternary Research Association New Research Workers' Award.

TABLE OF CONTENTS

LIST OF FIGURES

CHAPTER SEVEN: GEOCHRONOLOGY

CHAPTER EIGHT: DISCUSSION

LIST OF TABLES

CHAPTER FIVE: THE WESTERN SOLENT

CHAPTER SIX: THE BOURNEMOUTH REGION

CHAPTER SEVEN: GEOCHRONOLOGY

CHAPTER EIGHT: DISCUSSION

CHAPTER ONE: INTRODUCTION

1.1 Introduction and Rationale of the Thesis

A central theme of recent Quaternary research has been obtaining a clearer understanding of hominin populations during the Pleistocene, focussed on settlement history and technology/technological change. In northern Europe studies have been concerned with the effects of climate and changing environments and landscapes (e.g. Gamble 1986, 1992; Roebroeks *et al*. 1992; White & Schreve 2000; Ashton & Lewis 2002), as these are seen as primary influences on hominin colonisation and population dynamics (Chapter 2.2). Pleistocene fluvial terraces provide a fundamental resource for examining questions of hominin occupation (e.g. Wymer 1968, 1999; Bridgland 1994, 2000, 2010; Bridgland *et al*. 2004, 2006; Hosfield 1999; Ashton & Lewis 2002; Mishra *et al*. 2007; Brown 2008; Ashton & Hosfield 2010; Ashton *et al.* 2011; Briant *et al*. 2012) because they can produce coarse-grained, time averaged records of hominin presence. Terraces are important as both the major source of Palaeolithic archaeological material and as frameworks for contextualising that material.

The substantial archaeological resource of the Solent River system, found over a century of investigation (Chapter 2.2.3, 2.4), has recently been the focus of reinterpretation (Davies 2013). Currently the stratigraphic context of this record is not clearly understood, due partly to a lack of preserved biological material, making dating the region's terraces difficult, and the absence of a coherent basin-wide model of the terrace stratigraphy. The archaeologically important areas around Bournemouth to the west of the region and the Test Valley to the east are linked by the main Solent River deposits. Two recent reviews of the terrace stratigraphy in key areas of the Solent River system (Allen & Gibbard 1993; Westaway *et al*. 2006) produced very different interpretive models, and many issues remain unresolved (Chapter 2.4.2).

Primary requirements for a reappraisal of the archaeological record of the Solent River system region are a more complete understanding of: i) the regional stratigraphic fluvial sequences, in terms of both defining often fragmentary terrace units and producing a robust chronology for the evolution of those sequences; ii) inter-regional correlation of the three important areas of the Solent River system and iii) the construction of a revised Solent-wide stratigraphic sequence with chronological tie-points. In order to address these issues and enable the Solent River system to more fully contribute to current Quaternary research, this study sought to establish a revised regional stratigraphic model of the Solent River and its major tributaries based on new data. The sedimentological examination of stratigraphic sequences in the field, alongside a programme of optically stimulated luminescence (OSL) dating of fluvial terraces, ground penetrating radar (GPR) surveys and a re-assessment of the borehole archive and previous work in the region, contribute to this aim.

A lack of statistically significant lithological differentiation in the various terraces of the Solent River (Allen 1991; Allen and Gibbard 1993) and lack of preserved fossiliferous deposits in all but the lowest (last-interglacial) terraces means that geochronological methods such as OSL represent the most likely source of age-control or chronological tie-points (Chapter 7). It also necessitates the use of geomorphological approaches to the subdivision of the terrace stratigraphy of the Solent River system. Analysis of current stratigraphic models was based on extensive borehole data and results from new fieldwork, which enabled a reinterpretation of the terrace stratigraphies of the Solent River, the River Test and River Stour (Chapters 4, 5 and 6). The construction of long profile gradients aided correlation of the three elements of the Solent River system and provided the basis for a revised stratigraphic framework for the Palaeolithic archaeology of the Solent region (Chapter 8).

1.2 Aims and Objectives

The primary aim of the study was therefore to produce a revised interpretation of the Solent River system stratigraphic sequence and correlate archaeologically important regions of the system. In order to achieve this aim and better contextualise the Solent region four main objectives were formulated: i) To produce revised stratigraphic sequences for the Test Valley, Western Solent and Bournemouth regions; ii) To produce chronological tie-points for key terraces of the Solent River system; iii) To calculate downstream long profile gradients of the three main elements of the Solent

River system; iv) To correlate the revised stratigraphic sequences for the Test Valley, Western Solent and Bournemouth regions. A number of region or site-specific research questions were also addressed during the study as discussed in Chapters 4, 5 and 6.

1.3 Thesis Structure

Chapter 2 provides an overview of the Solent River system and recent research in the region. The chapter outlines the study area in terms of the pre-Quaternary geology of the Hampshire Basin, the regions' topography and drainage, and the Quaternary sedimentary record. The Pleistocene context of the Solent River system is examined in terms of climate and chronology, the palaeogeography of southern Britain and the hominin occupation of southern Britain from continental Europe. Recent conceptual models of fluvial terrace formation are outlined, and the correlation and dating of fluvial terraces and the construction of long profile projections are also discussed. Previous research into the Solent River system terrace stratigraphy is then reviewed before current stratigraphic models of the Solent River and its major tributaries are presented.

Chapter 3 describes the methods employed during the study to generate new stratigraphic and geochronological data and to critique previous models of the Solent River system stratigraphy. The chapter outlines how data and OSL samples were collected and goes on to describe the methodological approach for each technique in turn: borehole data analysis; the description and analysis of fluvial sediments and stratigraphy; optically stimulated luminescence (OSL) dating and ground penetrating radar (GPR). A new method of representing large volumes of linear stratigraphic elevation data such as that generated during this study is developed and described. Finally the methods used to construct long profile projections and terrace gradients are discussed.

Chapters 4, **5** and **6** present results from fieldwork conducted during this study in the Test Valley, Western Solent and Bournemouth regions respectively. The chapters examine fieldwork data collected by coastal and quarry section recording and GPR surveys, along with the available borehole data of each region. The terrace record of each region is then assessed within the stratigraphic models previously proposed, critiquing the stratigraphic ‘fit’ of new data collected during this study within each scheme. Finally a reassessment of the terrace stratigraphy of each region is made based on the generation of terrace reconstructions. These revised stratigraphies were achieved by means of a multi-stage method of long profile projection and terrace mapping analysis, in order to assess and revise current stratigraphic schemes.

Chapter 7 presents geochronological results from an extensive OSL programme carried out on 26 fluvial samples from seven locations in the Solent region. The chapter details an extensive programme of test procedures that were designed and employed in order to assess which samples would produce the most robust OSL age model. Issues encountered with the luminescence characteristics of those samples are discussed alongside implications for current age-estimates produced in the Solent River system.

Chapter 8 collates the various data sets from the preceding four chapters and presents revised interpretations of the stratigraphic record of the Solent River and its major tributaries. Long-profile projections of terrace deposits are presented through interpretation of fieldwork, borehole and GPR data. OSL data produced by the study, augmented by the most robust chronological data from previous studies, is used to propose a chronological sequence for the evolution of the terrace stratigraphy. These results are used to suggest regional correlations between the three study areas examined and construct a revised inter-regional stratigraphic framework with chronological tie-points. An assessment is then made of the methodological approach taken in the study to construct long profile projections and correlations. Finally, the potential affect that the reinterpretation of the terrace stratigraphy has on the context of the Palaeolithic archaeology of the Solent region is examined.

Chapter 9 summarises the conclusions from the study and goes on to discuss wider implications of the revised model on current Quaternary research concerned with Middle-Late Pleistocene hominin settlement history and technology in Britain.

CHAPTER TWO: THE SOLENT RIVER SYSTEM

2.1 The Study Area

The Solent River system drained the Hampshire Basin, which extends over southeast Dorset and south Hampshire on the modern south coast of the British Isles, throughout much of the Pleistocene period (Figure 2.1). The main Solent River flowed eastward across the basin and was joined by a series of tributary rivers and streams, finally draining into a major Channel River during glacial low-stand conditions, and into a marine embayment during interglacials (e.g. Darwin-Fox 1862; Evans 1864; Reid 1899, 1902a; White 1915, 1917; Allen and Gibbard 1993; Westaway *et al*. 2006). Holocene eustatic sea level rise has since drowned much of its course, but evidence remains in the form of fluvial aggradations. Lateral migration of both the main Solent River and the tributary rivers Test and Stour, preferentially downcutting into softer Tertiary bedrock rather than the aggraded terrace gravels (Westaway *et al*. 2006), resulted in the preservation of staircases of successive terrace landforms. These geomorphological features, less altitudinally distinct in the Western Solent region than on the valley sides of the River Stour and River Test (see Chapters 4, 5 and 6), collectively record the development of key elements of the Solent River system through the Middle and Late Pleistocene.

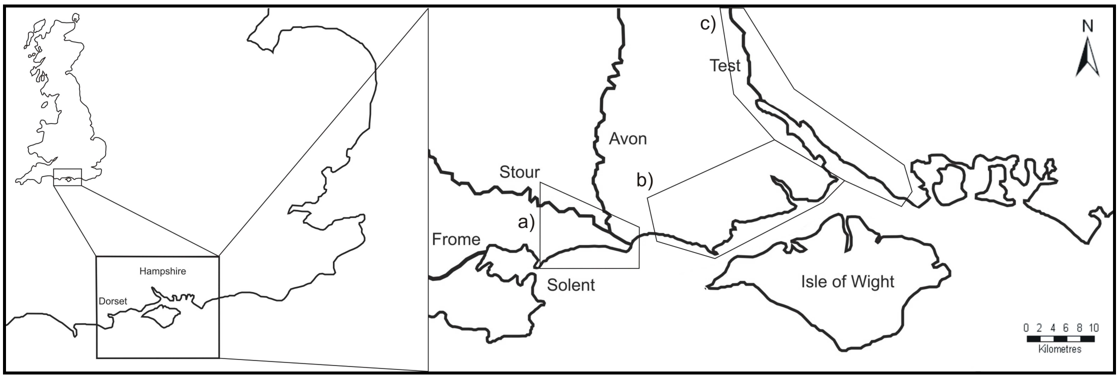


Figure 2.1. Location of the study area, showing a) the Bournemouth Stour/Solent region, b) the Western Solent region and c) the Test Valley region.

Three regions of the system are of particular archaeological importance and together form the study area for this thesis: the Bournemouth region comprising fluvial deposits of the River Stour and upstream Solent River; the Western Solent region comprising the main sequence of Solent River deposits; and the Test Valley region comprising the deposits of the River Test and the confluent Test/Solent.

2.1.1 Pre-Quaternary geology of the Hampshire Basin

The Hampshire Basin is a west-east orientated syncline filled with Quaternary superficial deposits overlying Cretaceous and Palaeogene bedrock geologies (Figure 2.2). The mid-Miocene Alpine Orogeny event, when the engagement of tectonic plates led to structural deformation of the region's lithosphere, formed a series of east-west and northwest-southeast orientated anticlines and synclines within the basin, as well as the Isle of Wight monocline, while compressing the late Cretaceous strata (Hopson 2009).

A comprehensive review of the pre-Quaternary geology and development of the region is provided by Stoneley (1982), Melville and Freshney (1985) and Hamblin *et al*. (1992). British Geological Survey (BGS) memoirs and mapping for the region have been produced by White (1915), Edwards and Freshney (1987), Bristow *et al*. (1991), Hopson (2000), Booth (2002), and the BGS (2009a-h).

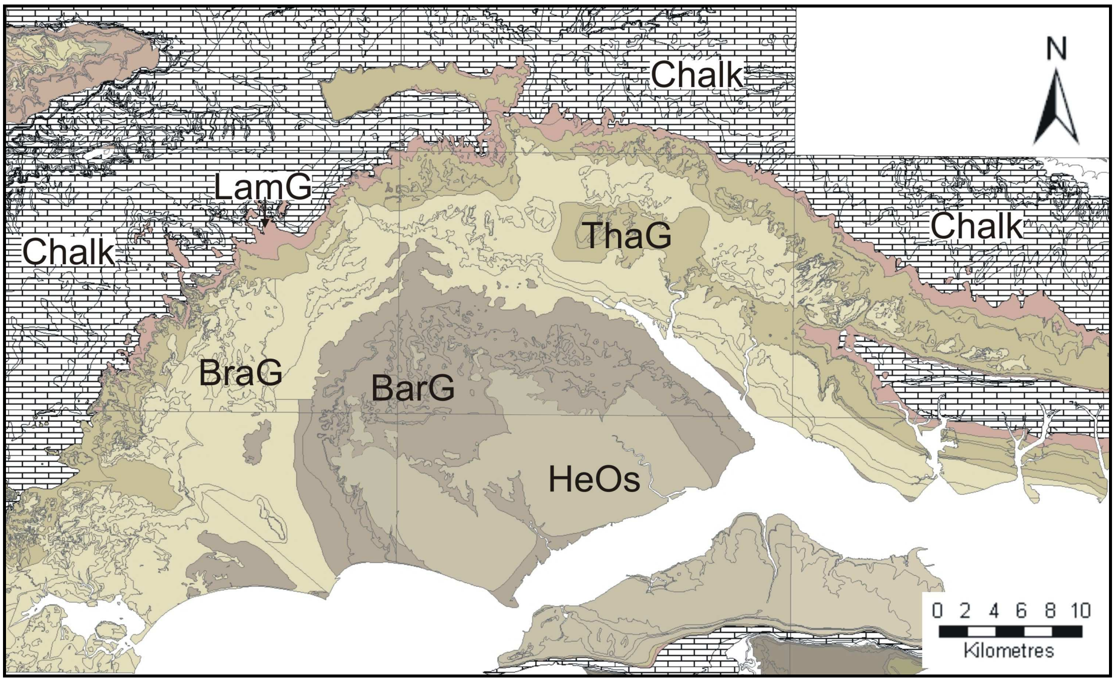


Figure 2.2. The bedrock geology of the Hampshire Basin region. BarG: Barton Group; BraG: Bracklesham Group; HeOs: Headon Beds and Osborne Beds (Undifferentiated); LamG: Lambeth Group; ThaG: Thames Group (BGS 2009a-h).

The basin is presently defined by the Cretaceous Chalk of the downlands to the north and the Wight-Purbeck monocline to the south. The Tertiary sediments that form the central deposits in the basin are predominantly sands, muds and marls, and silts and clays with occasional pebble-beds. The bedrock geology and form of the Hampshire Basin has had the primary influence on the distribution and lithology of the subsequent Quaternary deposits.

Table 2.1. The geological succession of the Hampshire Basin region (after Edwards and Freshney 1987; Bristow *et al*. 1991; Hopson 2001, 2009).

Period	Epoch	Lithostratigraphical units					Thickness
			Western Basin		Eastern Basin		
Quaternary	Holocene and Pleistocene		Artificial deposits, head, clay-with-flints, blown sand, aeolian deposits, peat, alluvium, alluvial fan, river terrace deposits. Marine, tidal river, raised beach and raised storm beach deposits.				Up to 10 m
Palaeogene	Eocene		Headon Formation			Lyndhurst Member	Up to 49 m
		Barton Group	Becton Sand		Becton Sand	Becton Bunny Member	6 to 70 m
			Chama Sand		Chama Sand		6 to 15 m
			Barton Clay	Warren Hill Sand	Barton Clay		26 to 80 m
			Boscombe sand				20 to 25 m
		Bracklesham Group	Branksome Sand (65 to 70) m		Selsey Sand (30 to 50m)		-
			Poole Formation	Parkstone Clay (0 to 22 m)	Marsh Farm Formation (18 to 25 m)		-
				Broadstone Clay (0 to 19 m)	Earnley Sand (0 to 24 m)		-
				Haymoor Bottom Clay (0 to 3 m)	Wittering Formation (23 to 57 m)		-
				Oakdale Clay (0 to 45 m)			-
				Creekmoor Clay (0 to 33 m)			-
		Thames Group	London Clay				30 to 110 m
	Palaeocene	Lambeth Group	Reading Formation				
Cretaceous			Chalk	Upper Chalk			258 to 315m
				Middle Chalk			52 to 61m
				Lower Chalk			38 to 81 m
			Upper Greensand				27 to 39 m
			Gault				20 to 40 m
			Lower Greensand				0 to 12 m
Jurassic			Various limestones, mudstones, siltstones and sandstones				15 to 162 m
Triassic			Various mudstones, limestones, sandstones, and siltstones				6 to 600 m
Permian			Mudstones and sandstones				0 to 865+ m

The basal strata in the region (Table 2.1) consists of a sequence of Permian (299-251 ma (million years ago)) and Triassic (251-199 ma) freshwater beds deposited before a late Triassic marine transgression that continued through the Jurassic (199-145 ma). The Late Cretaceous (99-65 ma) was a period of regional subsidence coupled with relative sea-level rise, which resulted in the deposition of the Greensand and Chalk groups. The overlying Palaeogene sedimentary record consists of a sand/clay sequence showing frequent marine transgressions of the region. The deposits represent an alternating series of freshwater fluvial and lacustrine sediments.

There then exists a ~25 ma gap between the youngest preserved Palaeogene deposits and the oldest Quaternary deposits in the region. The intervening sediments deposited during the late Palaeogene and Neogene were eroded after uplift along the Wealden axis, as part of the general inversion of the wider Wessex Basin in which the Hampshire Basin is located.

2.1.2 Topography and drainage of the Hampshire Basin

The topography of the Hampshire Basin (Figure 2.3) is still dominated by the series of synclines and anticlines formed by folds in the late Cretaceous strata described above. A key feature is the Isle of Wight monocline, which formed the south bank of the Solent River valley until its breach sometime in the Middle – Late Pleistocene (see 2.2.2 below). The Chalk ridge of the downlands to the north of the region is generally between 100 m and 200 m O.D., rising to ~280 m O.D. in places. The central depression of the basin consists of much dissected plateaus and flat-toped hills between around 30 m and 80 m O.D. The basin is currently drained by a series of rivers and smaller streams with their headwaters in the surrounding Chalk of the North Dorset Downs, Wiltshire Downs and Hampshire Downs. Principal amongst these are the River Frome, the supposed Upper Solent (see 2.4 below), the River Piddle, and the major tributaries of the Palaeo-Solent River: the River Stour, River Avon and River Test. Smaller elements of the system such as the Rivers Itchen and Hamble to the east and the Beaulieu and Lymington Rivers in the New Forest area are responsible for major dissection of the fluvial aggradations of the Test and main Solent respectively. The catchment of these elements of the Palaeo-Solent River system can be seen in figure 2.4 below.

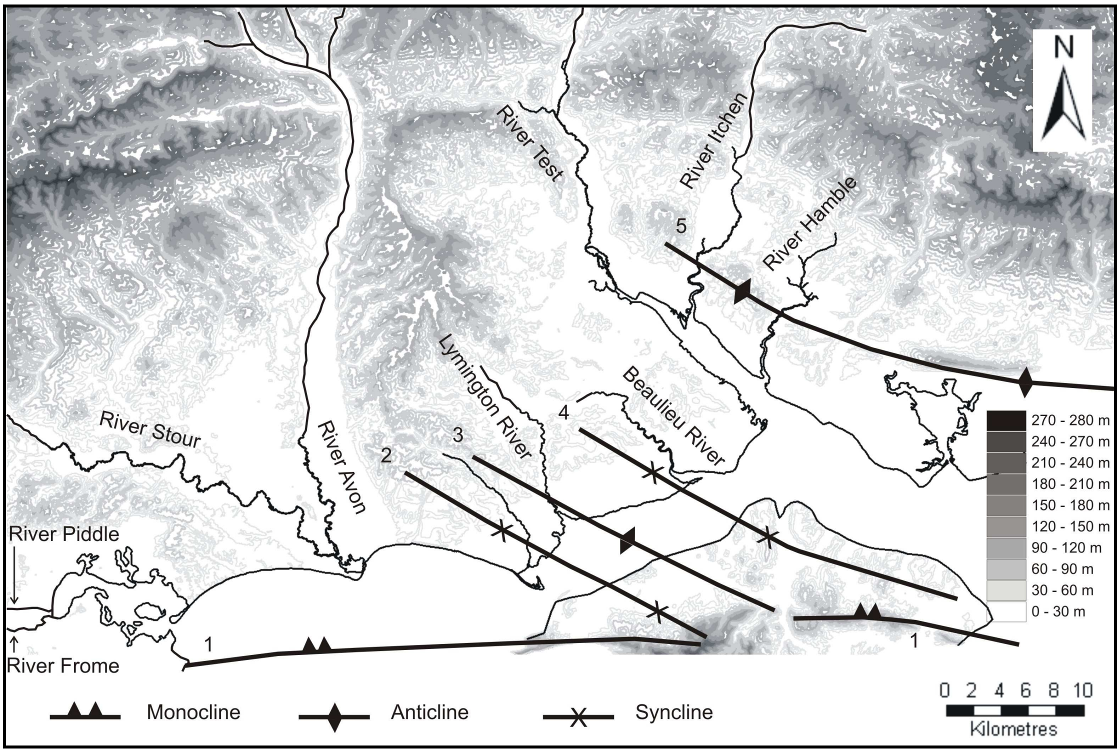


Figure 2.3. The topography and drainage of the Hampshire Basin region. (after Hopson 2009). Topographic features: 1 Isle of Wight monocline; 2 Bouldnor syncline; 3 Porchfield anticline; 4 Thorness syncline; 5 Portsdown anticline.

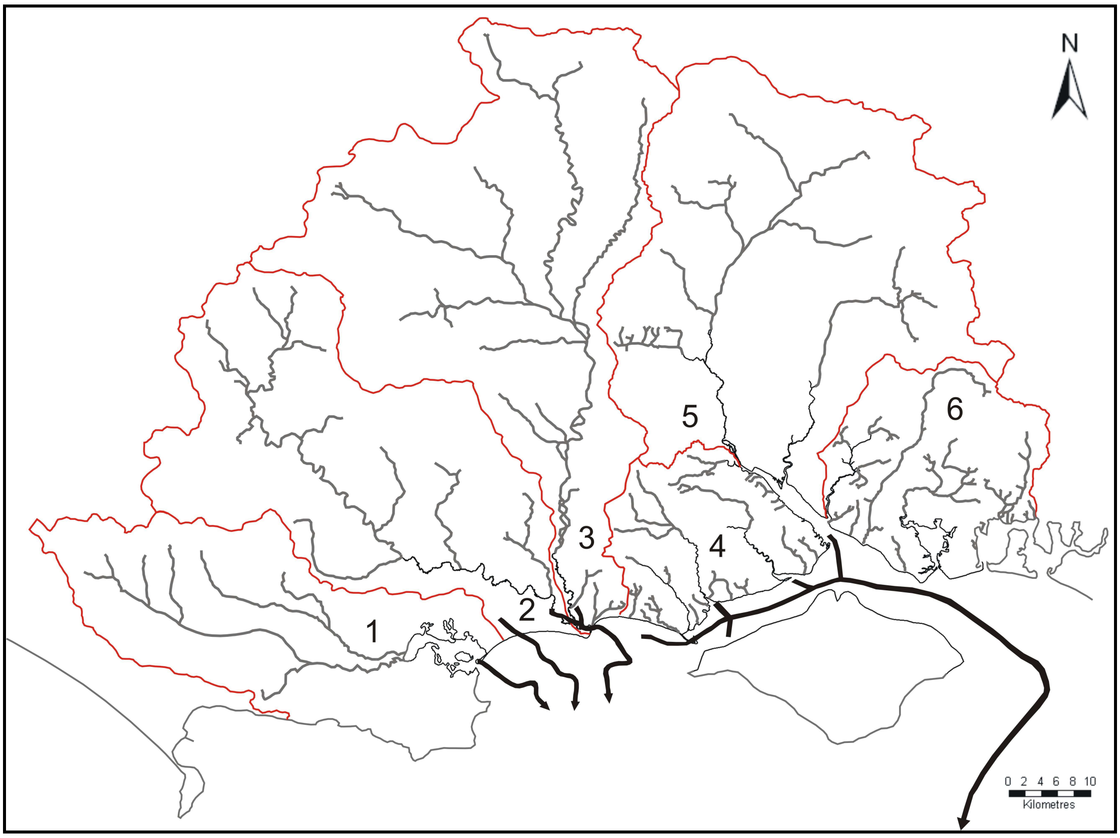


Figure 2.4. The final Pleistocene course of the Solent River system (MIS 2) with Holocene catchment areas of the Hampshire Basin region: 1. The Rivers Frome and Piddle and their tributaries; 2. The River Stour and its tributaries; 3. The River Avon and its tributaries; 4. The Lymington and Beaulieu Rivers and other minor western Solent rivers; 5. The Rivers Test and Itchen and their tributaries; 6. The River Hamble and other minor eastern Solent rivers.

2.1.3 Quaternary geology of the Hampshire Basin

The Quaternary sedimentary record in the Hampshire Basin largely consists of fluvial deposits, clay-with-flints, head, brickearth and alluvium, with marine and estuarine deposits in the east of the region (Edwards and Freshney 1987; Bristow *et al*. 1991; Booth 2002). The Pleistocene fluvial deposits form classic staircases of geomorphological terraces along the valley sides of the Rivers Stour and Test, as well as extensive, though often topographically less well defined, spreads in the Western Solent region. Cycles of downcutting and aggradation in conjunction with eustatic sea-level change and isostatic uplift resulted in the preservation of altitudinally distinct terrace levels, being oldest at the top of the sequence and youngest at the base. Each of the three fluvial elements studied (the Solent, the Test and the Stour) show that over successive climatic cycles preferential incision into the Tertiary bedrock of sands and clays has occurred, resulting in the lateral migration of each element and the gradual lengthening of the Test and Stour (Allen and Gibbard 1993). The Solent terrace sequence survives on the left bank of the valley, that of the Stour largely on its right bank, while the Test sequence survives on both banks as far south as Southampton Water, and then predominantly on the left bank of the Test Valley.

The fluvial deposits (Figure 2.5) are generally made up of flint-dominated gravels or sandy gravels, sometimes capped by clayey or sandy silts. The higher terraces are commonly clayey flint-dominated gravels. The lithological composition of the gravels of the Solent River as assessed by Allen and Gibbard (1993) comprises ~90 to 98% flint, with minor contributions of quartz, quartzite and Upper Greensand cherts amongst others.

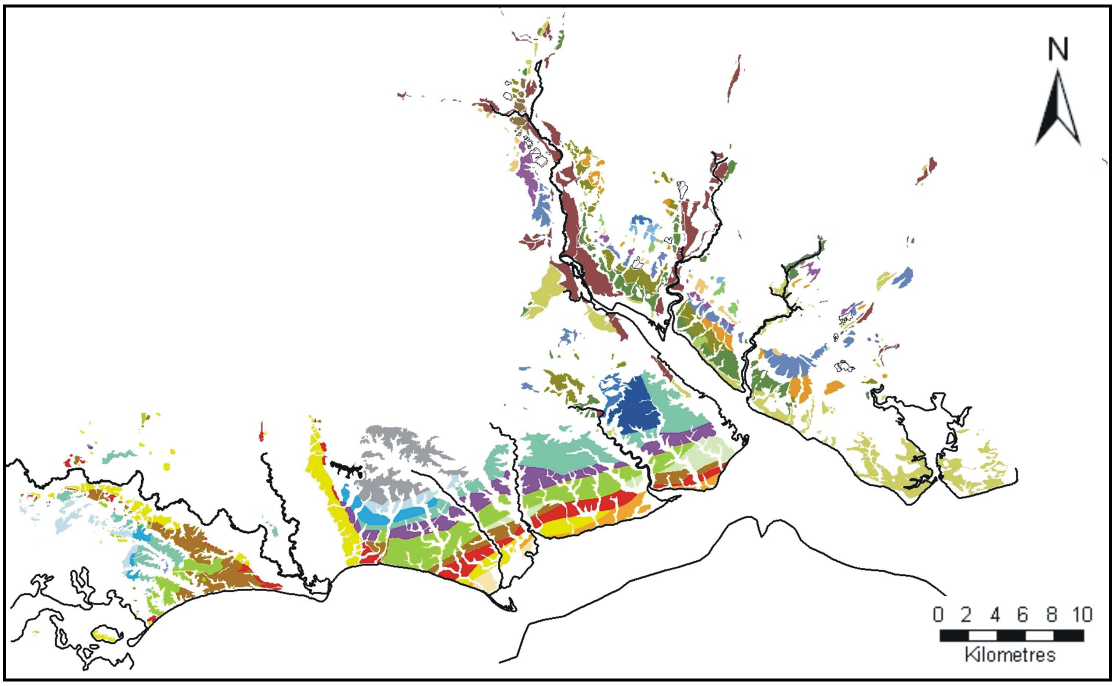


Figure 2.5. The Pleistocene fluvial aggradations of the Solent River system region. The specific stratigraphic schemes are described in Chapter 2.4.2 (Figures 2.13, 2.14, 2.15 and 2.16) and Chapters 4, 5 and 6.

The region lies beyond the extent of Middle Pleistocene glaciations (see 2.2.1 below; Figure 2.6), with the result that little sedimentary material was introduced into the Hampshire Basin. Therefore, other than within some of the oldest fluviatile or the marine deposits, the Quaternary sedimentation of the region comprises material derived from the Cretaceous and Palaeogene strata within the basin itself (Edwards and Freshney 1987; Bristow *et al*. 1991; Hopson 2009), with flint input from the Branscombe Pebble Beds, the Reading Beds or the extensive Chalk downland. The fluvial deposits are discussed more fully in section 2.4 below.

2.2 The Pleistocene context of the Solent River system

2.2.1 Climate and chronology

Three general patterns of Milankovitch orbital forcing influence climate at cool temperate latitudes in the Northern Hemisphere (Shackleton *et al*. 1990); precession cycles (~22 ka duration), obliquity cycles (~44 ka duration) and eccentricity cycles (~100 ka duration). Since ~0.9 ma extreme climatic variations on an eccentricity-cycle scale have dominated the region, with climate change also seen over ~22 ka and ~44 ka duration cycles, causing a climatic sequence of lowland glaciation and temperate conditions (Rose 2010a). The Solent region lay beyond the extent of Middle Pleistocene glaciations (Figure 2.6), and the region's climate cycled between periglacial and interglacial conditions. During this period of extreme peak discharges and abundant coarse-grained sediment supplied by glacial and periglacial processes, rivers were at their most geologically active (Rose 2010a) (Chapter 2.3). Climatic change influenced vegetation cover, precipitation and soil formation and erosion, each affecting fluvial discharge. These climate-driven processes provided the mechanisms required for incision and aggradation within fluvial systems. The corresponding changes seen in fluvial regimes such as the Solent River system are recorded in the sedimentary record (see 2.3 and 2.3.1 below).

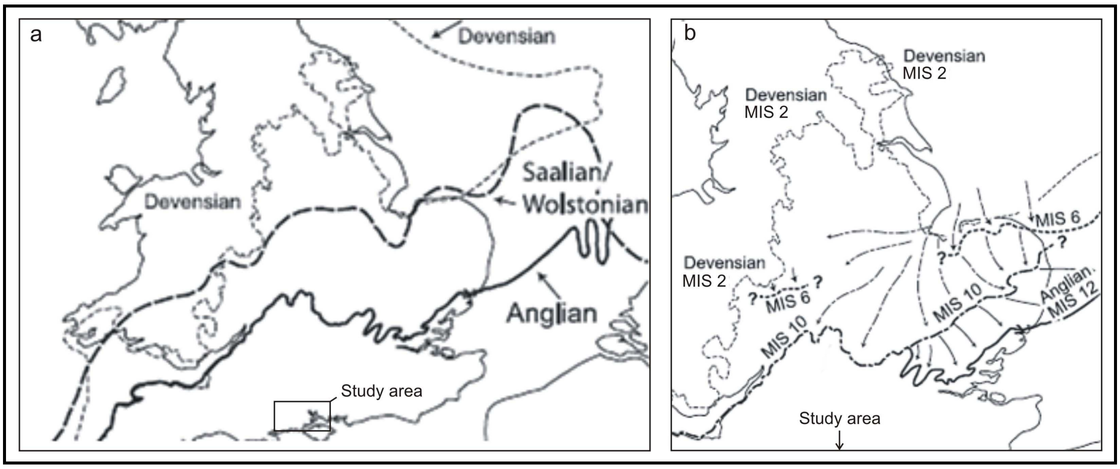
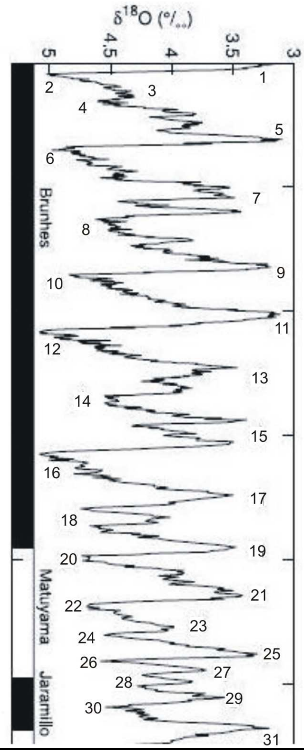


Figure 2.6. Extent of late Middle to Late Pleistocene glaciations in the British Isles. a) The 'traditional' model with a single late Middle Pleistocene (MIS 12) lowland glaciation (Gibbard and Clark 2011) and b) the multi-stage model of Clark *et al*. (2004) incorporating a MIS 10 glaciation (after Bose *et al*. 2012).

The Marine oxygen Isotope Stage (MIS) framework provides a global scheme for identifying distinct climatic periods. The most complete MIS curve of climatic change available is the LR04 curve of Lisiecki and Raymo (2005). Their MIS stack is constructed using benthic $\delta^{18}O$ records from 57 sites worldwide that span the last 5.3 ma, aligned by an automated graphic correlation algorithm. The improved signal quality of the stack shows significantly more variance than previously published stacks of the late Pleistocene due to higher resolution records, the alignment technique used and a greater percentage of records drawn from the Atlantic (Lisiecki and Raymo 2005). The ages of MIS boundaries in the LR04 MIS curve will form the basis for the chronology in this thesis, as seen in Figure 2.7.



Epoch	Age	MI Stage
Holocene	Present - 14,000	1
Late Pleistocene	29,000	2
	57,000	3
	71,000	4
	118,000	5a - d
	130,000	5e
Middle Pleistocene	191,000	6
	243,000	7
	300,000	8
	337,000	9
	374,000	10
	424,000	11
	478,000	12
	533,000	13
	563,000	14
	621,000	15
	676,000	16
	712,000	17
	761,000	18
	790,000	19

Figure 2.7. The last 1ma of the LR04 benthic $\delta^{18}O$ stack (left) with MIS boundary chronology (right) (after Lisiecki and Raymo 2005).

Climatic fluctuations during the Pleistocene had a dramatic effect on relative sea-level (Figure 2.8), which in turn would influence the palaeogeography of the Solent region and the location of base level as described in the next section. The recent sea-level curve of Rohling *et al*. (2009) shows the vertical range of sea-level since MIS 13 to be ~138 m.

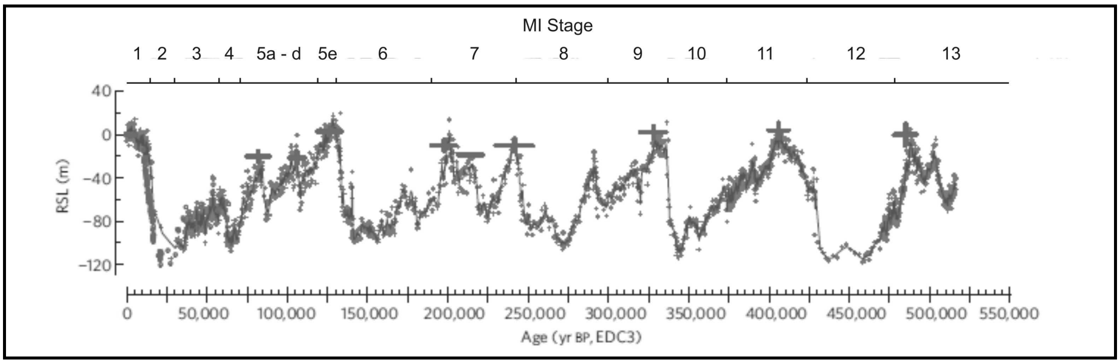


Figure 2.8. Relative Sea-Level (RSL) reconstruction curve of Rohling *et al*. (2009). Chronology based on EPICA Dome C ice-core Antarctic Temperature anomaly record of Jouzel *et al*. (2007) using a corrected EDC3 time scale (Parrenin *et al*. 2007), which brings it into close agreement with Lisiecki and Raymo (2005) (Rohling *et al*. 2010).

2.2.2 The Palaeogeography of Southern Britain

The Pleistocene palaeogeography of Britain and its connection to continental Europe was affected by both the rise and fall of sea-level during climatic cycles and changes to the form of the Dover Strait. Prior to the completion of the progressive breach of the Dover Strait between MIS 12 and 6 (Smith 1985; Gibbard 1995, 2007; Gupta *et al*. 2007; Hijma *et al*. 2012) the English Channel and North Sea regions were marine embayments during interglacial high-stands (Figure 2.9). A land bridge linked southeast Britain to northern France through the present Dover Strait, providing migrating hominins with unrestricted access to southern and eastern England. This Chalk ridge, the Weald–Artois anticline, was initially breached by the drainage of a pro-glacial lake in the North Sea Basin at the end of MIS 12 (Smith 1985; Gibbard 1995). The breach re-routed the Rhine-Thames river system to form the Channel River through the English Channel (Gupta *et al*. 2007). A further widening of the Dover Strait occurred prior to MIS 5e, isolating Britain to form an island during (high sea-level) interglacials (Gibbard 2007; Gupta *et al*. 2007). Even during low sea-level stands the now fully formed strait, containing the Channel River, would have been an increasingly substantial barrier. Data from ‘Fleuve Manche’ (Channel River) discharges during MIS 10, MIS 8, MIS 6 and MIS 4-2 confirms that the North Sea Basin was connected to the North Atlantic post-MIS 12 (Toucanne *et al*. 2009). These discharges increased in intensity, peaking during the MIS 6 event (Toucanne *et al*. 2009).

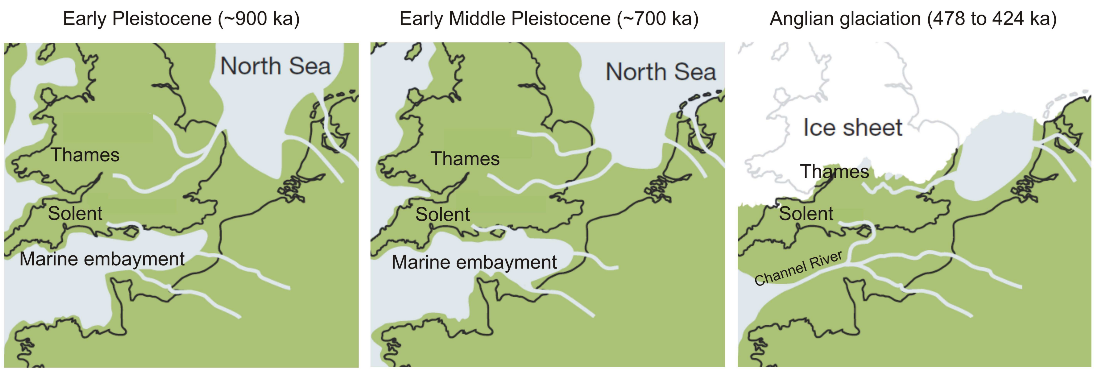


Figure 2.9. The changing palaeogeography of southern Britain and its connectivity to mainland Europe (after Parfitt *et al*. 2010).

There would have been regular estuarine flooding of the lower reaches of the Solent during the high sea-level stand events of interglacials. A reconstruction of the development of the nearby Sussex raised beaches by Bates *et al*. (2010) (Figure 2.10) shows the effect of high sea-level periods and the encroachment of estuarine conditions into the lower reaches of the main Solent and the River Test. Previous work has attempted to investigate the relationships between the fluvial deposits of the Eastern Solent/Test Valley with the beach sequences of West Sussex coastal plain on the basis of altitudinal differences, as the former lead laterally into the latter (Bates 2001). More recent work has attempted to determine those relationships by means of OSL and chronological correlation (Bates *et al*. 2010) as discussed in Chapter 8.1.

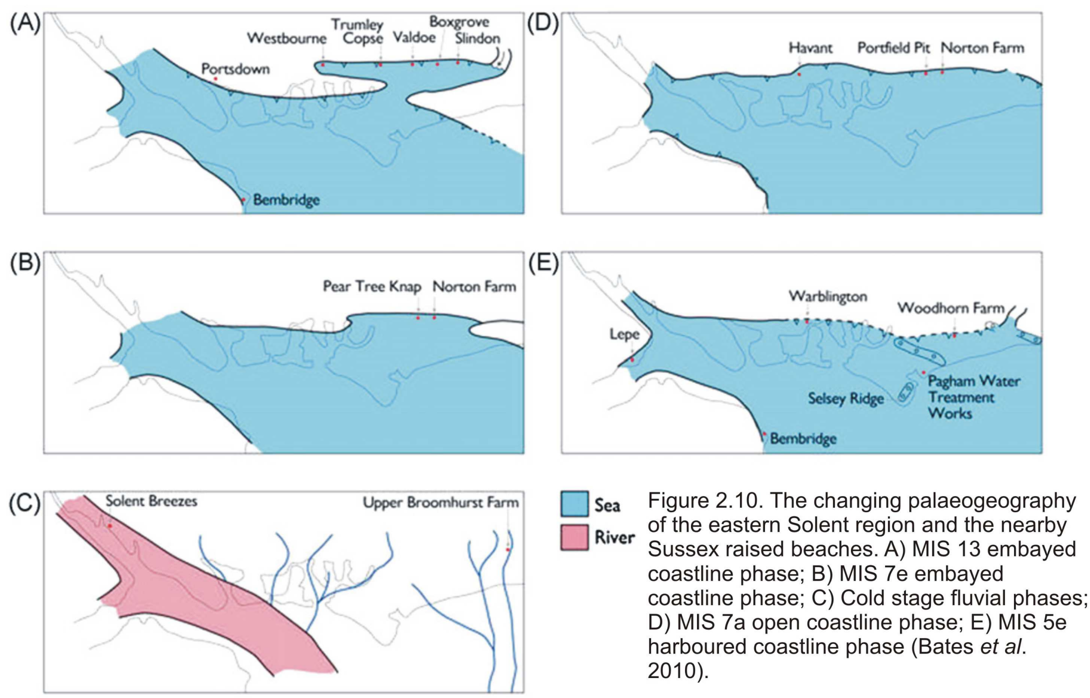


Figure 2.10. The changing palaeogeography of the eastern Solent region and the nearby Sussex raised beaches. A) MIS 13 embayed coastline phase; B) MIS 7e embayed coastline phase; C) Cold stage fluvial phases; D) MIS 7a open coastline phase; E) MIS 5e harboured coastline phase (Bates *et al*. 2010).

The Palaeo-Solent valley can be traced some distance off-shore. Sonar bathymetry of the English Channel south of the Solent region (Figure 2.11a) shows an extensive shelf at ~ -5 m O.D. to ~ -40 m O.D. (Gupta *et al*. 2007). The shelf stretches more than 40 km offshore from the current south coast of Britain until it reaches an east-west trending escarpment that defines the northern limit of the Channel River Palaeo-valley. The confluence of the Solent River with the Channel River during low sea-level stages is located at this scarp, as the surface relief drops rapidly to ~ -60 m O.D. Figure 2.11b shows the approximate (much modified) profile of the offshore Palaeo-Solent valley using data derived from the bathymetric image (Figure 2.11a). Projecting a long profile from the lowest Solent terrace to the location of the Solent/Channel River confluence produces a gradient of 0.59 m km^{-1}.

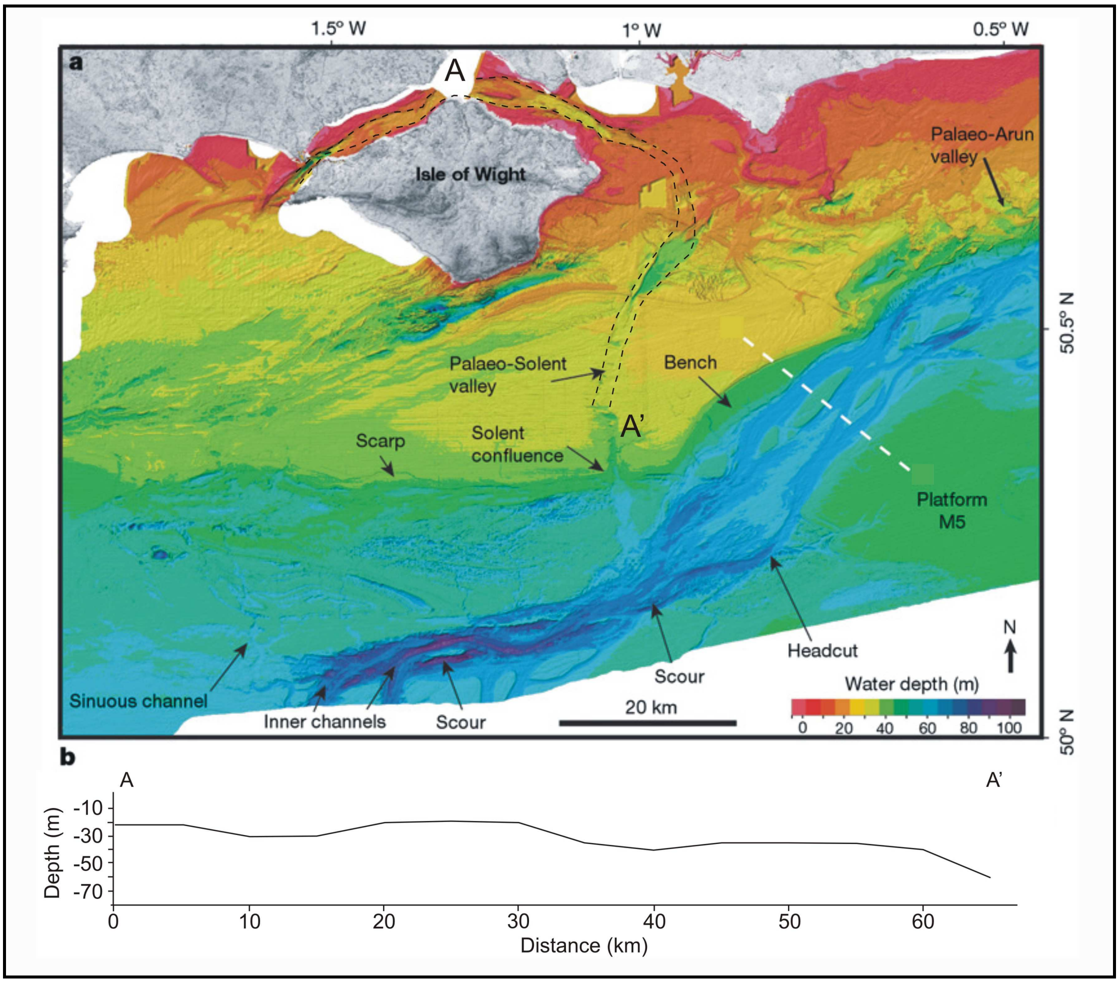


Figure 2.11. a) Coloured relief Sonar bathymetry map of the north-central English Channel with the Solent Palaeo-valley highlighted. b) Approximate profile of the Palaeo-Solent valley using data derived from (a), showing evidence of more recent scouring in the modern Solent Strait around the Isle of Wight (e.g. the first ~20 km of the profile). Modified from Gupta *et al*. (2007).

The changing palaeogeography of southern Britain would have influenced the hominin settlement history of the region (e.g. Preece *et al*. 1990; Gibbard and Allen 1994; White and Schreve 2000; Ashton and Lewis 2002; Lagarde 2003; Ashton and Hosfield 2010; Bates *et al.* 2010; Rose 2009; Rose 2010a; Ashton *et al*. 2011). Through the Middle Pleistocene successive migrations across the North Sea Basin into eastern Britain would have been presented with a developing channel feature to negotiate during interglacials, with a Channel River present during cooler glacial-interglacial transition periods. The route from continental Europe into the Solent Region would have been more problematic after the breach of the Dover Strait, with access possibly limited to cooler periods with associated lower sea-levels. It is likely that these two regions represented different challenges for colonising hominins at different times (Ashton *et al*. 2011). Subsequent to the breach of the Dover Strait the archaeological record of the two regions also appears to reflect populations entering southern Britain from different areas of northern Europe (Ashton and Hosfield 2010) as discussed below.

2.2.3 The hominin occupation of Southern Britain

The colonization of Europe by hominins during the Pleistocene followed their dispersal out of Africa around 1.9 ma. The record of their migrations are fragmentary and constantly reassessed as new evidence comes to light (e.g. Carbonell *et al*. 1995; Carbonell *et al*. 2008; Gabunia *et al*. 2000; Dennell 2003; Brown *et al*. 2004, Morwood *et al*. 2004; Krause *et al*. 2010; Mosquera *et al.* 2013). Key sites that identify early hominin presence in Europe include the remains from Gran Dolina (Atapuerca TD6) Spain (~780 ka ago) (Carbonell *et al*. 1995), Monte Poggiolo, Italy (~850 ka ago) (Falguères 2003; Arzarello and Peretto 2010; Muttoni *et al*. 2011), Sima del Elefanti (Atapuerca TE9), Spain (~1.2-1.1 ma ago) (Carbonell *et al*. 2008), Orce (Barranco León and Fuente Nueva), Spain (~1.3-1.2 ma ago) (Oms *et al*. 2000; Arribas and Palmqvist 2002; Toro *et al*. 2009) and Pirro Nord, Italy (~1.6 ma ago) (Arzarello *et al*. 2007, 2012; Arzarello and Peretto 2010; cf. Muttoni *et al*. 2011). Such early evidence is consistent with hominin evidence at the ‘gateway to Europe’ from Dmanisi, Georgia dated to ~1.85 ma (Gabunia and Vekua 1995; Gabunia *et al*. 2000; Ferring *et al*. 2011).

Until relatively recently the earliest evidence for hominin occupation in northern Europe was believed to be ~500 ka (MIS 13) (Dennell and Roebroeks 1996), although sites of potentially greater antiquity were known. Sites such as Boxgrove (UK) (Roberts and Parfitt 1999) and Mauer (Germany) (Howell 1960; Rightmire 1998) provided definitive evidence of human presence, with well-dated hominin remains and lithic artefacts. The pattern of evidence indicated a 'revised short chronology' of colonisation (Dennell and Roebroeks 1996; Roebroeks 2001, 2006), with a background of hominin presence before a noticeable increase in evidence after ~600-500 ka. The lithic evidence recently discovered at Pakefield in Suffolk (~700 ka; MIS 17 or the latter part of MIS 19) (Parfitt *et al*. 2005; cf. Westaway 2008) and Happisburgh 3 (between 990 ka and 780 ka; MIS 21 or 25) (Parfitt *et al*. 2010; cf. Westaway 2011) has shown hominin presence in Britain earlier than previously confirmed, but possibly not of sufficient quantity to disprove Roebroeks' (2001) revised short chronology (Hosfield 2010). The archaeological pattern would seem to support sporadic occupation (probably during climatic optima) before MIS 13, with a population peak in MIS 13 and MIS 11, declining thereafter (Ashton and Lewis 2002; Ashton and Hosfield 2010; Ashton *et al.* 2011).

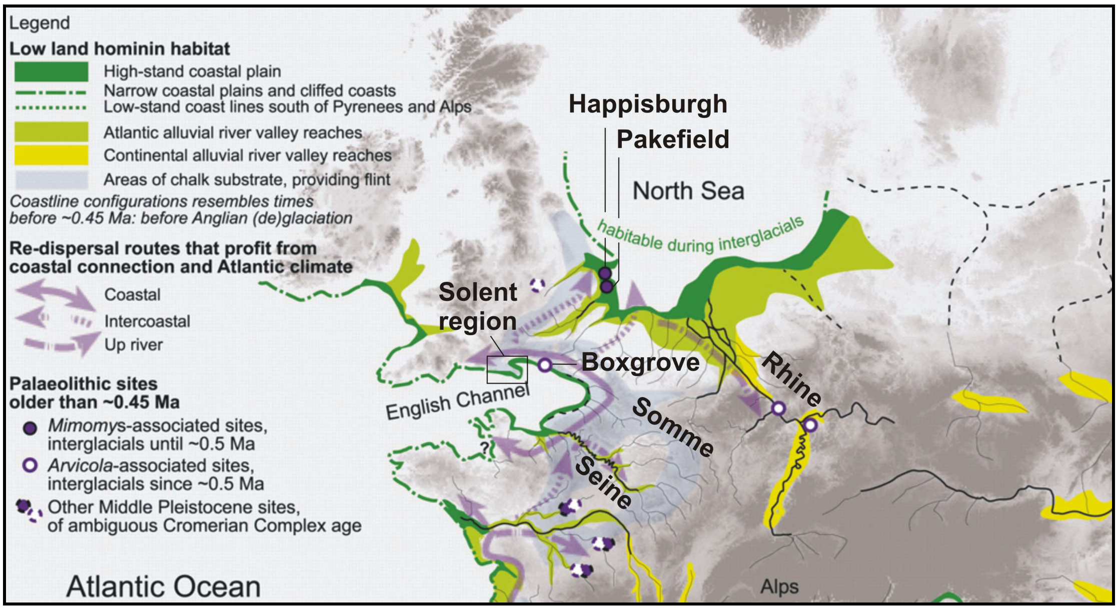


Figure 2.12. North-west Europe's Atlantic climate coastal zones and river networks as Lower Palaeolithic hominin dispersal pathways (after Cohen *et al.* 2012).

Prior to the breach of the Dover Strait coastal dispersal would have provided hominins with access to southern Britain from continental Europe (Cohen *et al.* 2012; Figure 2.12). Throughout the Pleistocene Britain would have been linked via the major river valleys of northern Europe, which is demonstrated by the location of sites such as Happisburgh and Pakefield as well as the key regions showing more extensive occupation histories, those of the Thames and Solent river systems. The Solent region would have been accessed via major palaeo-valleys in north-western France such as the Somme and Seine, while the Thames and East Anglia regions would have linked to the Rhine, Meuse and other rivers further north.

The archaeological record of the Solent Region has been studied, though rarely published (Bury 1923, 1925; Burkitt *et al*. 1939; Calkin and Green 1949; Roe 1968; Shackley 1970; Wymer 1999; Hosfield 1999; Ashton and Hosfield 2010), since the late 19th century and represents a significant resource. The evidence of the River Thames region currently shows the most complete record of hominin presence in Britain over the last ~500 ka (e.g. Gibbard 1985, 1994; Bridgland 1994; Wymer 1999; Ashton and Lewis 2002; Ashton *et al*. 2011). The Solent River has a fluvial sequence spanning the Pleistocene and potentially into the Pliocene (Reid 1902; Allen and Gibbard 1993; Gibbard and Preece 1999). However the Solent archaeological record, by comparison to that of the Thames, is fragmentary with poor chronological control (e.g. Allen 1991; Allen and Gibbard 1993; Wessex Archaeology 1993; Wymer 1999; Bates *et al*. 2004; Westaway *et al*. 2006; Briant *et al*. 2009a; Hosfield 2009; Ashton and Hosfield 2010). This has limited the contribution that the Solent region can make to the full story of the hominin occupation of Pleistocene Britain.

The Solent region’s gravel terraces have been found to be rich in archaeological evidence, with more than 8,500 handaxes discovered (Hosfield 1999, p.23 Table 2.1) over more than a century of investigation. Ashton and Hosfield (2010) compared the available Solent archaeological record (restricted to handaxes due to the low number and poor contextual information of Levallois artefacts) to that of the Thames (Ashton and Lewis 2002) and found a broadly similar pattern of peak populations between MIS 13 to MIS 10, declining from MIS 9 onwards. In the Middle Thames the archaeological record showed peak populations between MIS 13 to MIS 11, which then declined, with no clear evidence for artefacts from late MIS 7 or early MIS 6 until late MIS 4 (Ashton and Lewis 2002; Ashton *et al.* 2011). The Solent record will require reassessment in light of the revised stratigraphic framework presented here (Chapter 8.3).

2.3 Processes of fluvial terrace formation and their analysis

The formation and preservation of fluvial terraces are controlled by a range of complex, co-dependent internal and external variables. In broad terms fluvial systems aggrade when sediment supply exceeds transport capacity; where this occurs within a drainage network feeding a main valley axis, such as the Solent, sediment overloading will produce a relatively constant thickness of channel-bed aggradation (Blum and Törnqvist 2000). When conditions result in transport capacity exceeding sediment supply, whether induced by upstream or downstream controls (Blum and Törnqvist 2000), degradation leads to net sediment removal, channel incision and floodplain abandonment. Incision occurs as a fluvial system adjusts its longitudinal gradient after disequilibrium or disturbance, and like aggradation is a "deviation from grade" (Leopold and Bull 1979).

Evidence for the influence and impact of climate on the nature of fluvial sediments and landforms are numerous (Vandenberghe 2003). Patterns of landform evolution may also be influenced by internal controls and feedback mechanisms within fluvial systems (Schumm 1977, 1979; Hey 1979; Bull 1991). The seasonal distribution and intensity of precipitation is important in determining processes of erosion and deposition within river systems, with extreme events of seasonal or decadal frequency particularly significant (Vandenberghe 2003). The extent of topographic relief, together with discharge, will determine the available energy in a fluvial system (Lane 1955). In addition topography, valley width and subsoil lithology will determine the available energy conditions or 'accommodation space' for fluvial development within the fluvial system (Rose 1995; Kasse 1998; Mol *et al*. 2000). Vegetation cover, and changes in vegetation type and density, will control surface sediment erosion and induce short periods of river instability (Vandenberghe 1993, 1995, 2001). Such internal influences affecting channel geometry, discharge and sediment supply and external variables such as climate, eustatic sea-level change and tectonic activity, interplay over a variety of spatial and temporal scales to influence fluvial development.

In order to produce and preserve a sequence of successive, altitudinally distinct terrace levels, uplift of the landmass is generally required (Antoine 1994; Bridgland

1994; Van den Berg 1996; Maddy 1997). The form of uplift can vary (and interplay) over time, with principle mechanisms deriving from regional tectonic activity, epeirogenic uplift on a broader scale, and isostatic or eustatic responses (Lewin and Gibbard 2010). The influence of uplift may be viewed as a driving or generating factor in terrace formation (Maddy 1997; Westaway *et al.* 2002; Bridgland and Westaway 2008a). On the timescale of a glacial-interglacial cycle however, prior uplift may be taken as an enabling rather than generating factor (Lewin and Gibbard 2010). Indeed while local slope is affected it is likely that the direct influence of uplift to catchment sediment change is minor compared to climatically controlled sediment supply and transport (Brown *et al*. 2009). While studies have measured uplift via the height differential between terrace levels (Maddy 1997; Maddy and Bridgland 2000; Maddy *et al.* 2000) and further modelled the timing of uplift in specific regions/sequences (Westaway *et al.* 2006; Bridgland and Westaway 2008b), it is likely that on the scale of individual climatic cycles the pace and duration of geomorphological processes will also influence any such height difference (Lewin and Gibbard 2010). Whether enabling or driving, the processes of uplift provide the backdrop to the primary generating factors of terrace formation, long recognised as being climatic in nature (Zeuner 1945; Bourdier 1958; Wymer 1968).

In the Solent region these geomorphological landforms take the form of bedrock-cut ‘strath’ terraces (Leopold *et al.* 1964). Terrace deposits may consist of a variety of sedimentary forms and sequences reflecting alluvial aggradation prior to incision and the resulting terrace formation. In some cases terraces aggradations consist of cold-climate, coarse-grained sands and gravels covered by fine-grained interglacial deposits such as the Moselle (Cordier *et al.* 2006) and Somme in northern France (Antoine *et al.* 2007), and the Maas, southern Netherlands (Van den Berg 1996). As exemplified by the classic Thames sequence terraces may also consist of a ‘sandwich’ of thin basal cold-climate gravels, interglacial sediments and thicker upper cold-climate gravels (Bridgland 1994, 2000; Bridgland and Allen 1996). The terraces in the Solent system appear to have aggraded predominantly under cold-climate conditions (Allen and Gibbard 1993) as there are no identified interglacial deposits in all but the lowest terrace, but they lack definitively diagnostic evidence.

2.3.1 Models of fluvial terrace formation

Although climatic influences on terrace formation had been identified, a climatic interpretation of the processes of terrace development did not initially gain prominence (Clayton 1977). Green and McGregor (1980) identified a lack of research into both the geomorphological processes of Pleistocene fluvial systems and the environmental factors that influenced those geomorphological processes, and proposed a scheme of terrace development (ibid). Further work began to identify potential phases of terrace-forming activity and the subsequent sequences of terrace development over time (Green and McGregor 1987). Such approaches demonstrate that the geomorphological and stratigraphical interpretation of fluvial systems and terraces are complex and require a cautious approach (McGregor and Green 1983a; Green and McGregor 1987).

Following on from these early schemes three conceptual models have recently been developed to explain the fundamental processes that result in terrace formation, with approximate correlation of the various stages involved (Table 2.2). Although not directly comparable due to the different scales of phases/stages employed, the three schemes do propose mechanisms for, and timings of, the key stages of terrace formation (erosion and deposition of sediments). While each scheme covers a single glacial-interglacial climate cycle the stages described should not be considered as rigid; Lewin and Gibbard (2010) state that their fluvial phases could be strongly influenced by local conditions, overlap and/or grade into one another and are likely to represent interglacials of varying length. As discussed below the key differences between the models are the timing and frequency of erosional and depositional events that contribute to terrace formation.

As originally conceived to explain the fluvial sequence of the Lower Thames (Bridgland 1994, 1995, 2000, 2001, 2006; Bridgland and Maddy 1995; Bridgland and Allen 1996), the so-called “Bridgland model” (Rose 2006) relates river activity to 100 ka Milankovitch-scale climate forcing, with terrace formation occurring at the warming limb of the climatic cycle (Bridgland and Maddy 1995). The model was adapted (Bridgland 2000) to incorporate a second (potential) terrace forming phase and used to account for the record of the main Solent River (Bridgland 2001), where it appears that more terraces survive than the available 100 ka cycles. Further work led to the proposition of Milankovitch-substage fluctuations accounting for the Solent record of closely paired terraces, as modelled by Westaway *et al*. (2006). Bridgland and Westaway (2008) concluded that incision can occur at either cold-warm and/or warm-cold transitions. The current six-stage model (Table 2.2) envisions a stable glacial phase followed by late glacial erosion (and terrace formation) followed by floodplain aggradation. Interglacial aggradation is followed by a further (usually minor) erosional phase, potentially causing terrace formation. The main aggradation phase then occurs during climatic deterioration early in the next glacial phase. The Bridgland model is well established in the British (especially archaeological) research community and has been used across the globe (Bridgland *et al*. 2004; Lee *et al*. 2004; Boenigk and Frechen 2006; Bridgland and Westaway 2008).

Gibbard and Lewin (2002; Lewin and Gibbard 2010) interpret the terrace sequences of south and east England to be predominantly formed by cold-climate processes. Furthermore, rather than reflecting brief or transitional episodes at cold-warm and warm-cold phases (Bridgland and Westaway 2008; Vandenberghe 2008, but see below) incision is seen as predominantly occurring early in cold stages as described by Antoine *et al*. (2000, 2007). Transitional phases are thought to produce a reworking of sediments rather than bedrock incision, and interglacial activity is seen as having a limited land-forming effect (Lewin and Gibbard 2010). The model (Table 2.2) describes valley evolution and sedimentation through an interglacial stage with additional phases accounting for glacial-periglacial periods. Erosion occurs early in the glacial phase into fully glacial conditions, followed by full/late glacial braidplain aggradation. Warm-stage aggradation occurs throughout interglacial phases as the river and channel form develops, before the onset of early glacial conditions and a return to erosional processes.

Table 2.2. Fluvial process models produced by Bridgland (1994, 1995, 2000, 2001, 2006); Gibbard and Lewin (2002; Lewin and Gibbard 2010); and Vandenberghe (1995, 2001, 2008).

Phase/*Mode*	Bridgland model	**Phase**/*Mode*	Gibbard & Lewin model	**Phase**/*Mode*	Vandenberghe model (Lowland setting)
Glacial *Stable*	Relatively stable glacial maxima; restricted fluvial activity with a seasonal melt-water pulse [Phase 6]	**Early/Full glacial** *Erosion*	Incision/gullying; rare sedimentation; debris in transport; sediment removal/erosion of substrate; ?single channel form	**Glacial** *Glacial floodplain aggradation*	Braided and wandering fluvial pattern with high width-depth ratio; coarse-grained braided deposits; wider floodplains with well expressed terraces formed by later dissection; aggradation often alternating with erosion at high peak discharges
Late glacial *Erosion*	Downcutting of valley floor during high discharge; on warming limb of climatic cycle; extent controlled by base level; terrace formation [Phase 1]	**Full and Late glacial** *Gravel braidplain aggradation*	Lateral accretion and aggradation of gravel and sand in braidplain; braided channel form		
Late glacial *Gravel floodplain aggradation*	Aggradation of sand and gravels on warming limb of climatic cycle [Phase 2]			**Late glacial/ Early interglacial** *Incision*	Incision of deep but limited lateral extent at warming [cold-warm] transition
		Early interglacial *Interglacial aggradation*	Deposition and vertical accretion of fossiliferous marl, tufa, organic mud and silt in channels and depressions; inherited multiple, stable channel form [Fph I]		
Interglacial *Interglacial aggradation*	Deposition of interglacial deposits; usually in single thread channels; estuarine sediments in lower reaches of valley [Phase 3]	**Full interglacial** *Interglacial aggradation*	Channel deposition and vertical accretion of fossiliferous detritus/clay or silt mud and peat in depressions, channels and floodplain; few to multiple channels, anastomosing channel form [Fph II]	**Interglacial** *Interglacial floodplain aggradation*	Meandering (single-thread) or anastomosing (multi-thread) with small width-depth ratio; constrained alluvial plain during stability phases
		Full interglacial *Interglacial aggradation*	Channel deposition, vertical accretion and channel avulsion of remaining depressions of fossiliferous detritus/ clay/silt mud, peat, silt and clays; floodplain surface becoming planar; inactive meandering, anastomosing channel form [Fph III]		
Late interglacial *Erosion*	Minor erosion on the cooling limb of interglacial; removal and/or reworking of existing floodplain deposits [Phase 4]	**Late interglacial** *Interglacial aggradation*	Vertical accretion and ?channel avulsion of silts and clays ± plant and animal remains; planar floodplain surface; single to multiple channel form [Fph IV]		
Late interglacial/ Early glacial *Gravel aggradation*	Main aggradation phase; climatic deterioration and declining interglacial vegetation leads to increased discharge and enhanced sediment supplies [Phase 5]	**Early glacial** *Erosion*	Vertical accretion, deposition giving way to incision and gullying of sand sheets, silts and clay drapes; floodplain splays; enlarging channel and lateral accretion; ? channel form	**Late interglacial/ Early glacial** *Incision*	Incision of shallow but wide lateral extent at cooling [warm-cold] transition

Vandenberghe (1995, 2001, 2008) develops a critique of traditional one-to-one correlation of fluvial morphological processes and climate, noting that unequal river activity at cold-warm and warm-cold transitions produces valleys dominated by cold-stage terraces. The model (Table 2.2) recognises that the two incision events within a single climatic cycle have varying morphological effects, which explains the relative scarcity of warm-climate interglacial terrace remnants (Vandenberghe 2008). The glacial phase sees floodplain aggradation (with a high width-depth ratio) alternating with erosion at peak discharges, followed by terrace forming incision of deep but limited lateral extent at the early interglacial cold-warm transition. Interglacial aggradation (with a low width-depth ratio) is followed by shallow incision of wide lateral extent at the early glacial warm-cold transition

The data produced by this study was examined in terms of the fundamental differences in the timing and frequency of erosional and depositional events predicted by the Bridgland, Gibbard and Lewin and Vandenberghe models (Chapter 8.3 below). The terrace stratigraphy proposed for the Solent River system was then assessed in light of the different fluvial patterns that are predicted by these models (see Table 8.3).

2.3.2 Correlating and dating fluvial terraces

The construction of stratigraphic and geochronological frameworks for sedimentary sequences, such as the revised terrace stratigraphies developed in this thesis, can be achieved by a number of methods. Lithostratigraphy, biostratigraphy and geochronology may be used to order, correlate and/or date fluvial sequences. Additional challenges regarding scale are introduced when units are fragmentary and spatially dispersed as seen in the Solent River system, where distances between deposits and/or data points can be in the order of kilometres.

Sedimentary information forms the foundation of any stratigraphic determination of deposits, fundamentally expressed in the Law of Superposition which dictates that any deposit will be younger than the deposit on which it rests (where the sequence is undisturbed). Such data provides the simplest evidence of the relative age and ordering of deposits within a sequence, but is limited by the ability to trace continuous exposures. The concept of sedimentary facies is central to the depositional and environmental interpretation of sediments and can be utilised to aid correlation of discontinuous deposits. Inferences of environmental conditions are based not only on the vertical sequence encountered in aggradations but also lateral relationships. Such approaches have been applied, for example, to varied ancient sandstone sediment bodies (Miall 1988; Bromley 1991a, 1991b; Cowan 1991; Lang and Fielding 1991; Wizevich 1992; Muñoz *et al*. 1992; Clemente and Pérez-Arlucea 1993; Stephens 1994), to conglomeratic braided stream deposits (Smith 1990) and to conglomeratic alluvial-fan deposits (DeCelles *et al*. 1991; Soegaard 1991). It has also been utilised extensively in the River Thames valley (e.g. Bridgland 1994; Gibbard 1985, 1994; Maddy *et al*. 1998; Lewis and Maddy 1999; Lewis *et al*. 2001, 2006).

Lithostratigraphy, based on the identification of lithologic characteristics of sediments, may be used to define, order and correlate aggraded units up to the system-wide scale. *In situ* examination of sediments in conjunction with laboratory based tests can investigate (e.g.) pebble lithology, grain size and palaeocurrent. Lithostratigraphic approaches have proved successful in understanding many fluvial systems, such as the evolution and development of the Thames system (e.g. Green *et al*. 1982; Green and McGregor 1983; McGregor and Green 1983b, 1986). The homogonous nature of the apparently cold-climate sediments found in the Solent terraces (see 2.1.3 above) make lithostratigraphical correlation difficult in terms of defining identifiable characteristics of discrete and discontinuous aggradations.

Biostratigraphy is generally able to correlate geographically distinct sediments based on the presence (or absence) of distinctive fossil evidence, producing relative age sequences or approximate time-correlations. The identification and development of distinctive faunal groupings and the ‘mammalian assemblage-zone’ scheme (Sutcliffe 1976; Currant 1989; Lister 1992; Schreve 2001a and 2001b) has enabled differentiation of British interglacials based on diagnostic markers, and has also been used to produce age models potentially to a MI substage level (Schreve 2001b). However, the Solent region largely lacks biostratigraphic remains due to preservation issues caused by the prevailing groundwater conditions. The pre-Quaternary geology of the region consists largely of Palaeogene clastic bedrock, resulting in non-calcareous groundwater which prevented the preservation of fossiliferous sediments in all but the lowest terraces in the sequence. This has limited the biostratigraphic information available in the region.

Geochronological approaches such as Electron Spin Resonance (ESR) (Laurent *et al*. 1998; Grün and Schwartz 2000; Falguères 2003), Amino Acid Racemisation (AAR) (Penkman *et al*. 2007, 2008), Uranium-series dating (Rowe *et al*. 1997, 1999; Grün and Schwartz 2000; Candy and Schreve 2007) and Optically Stimulated Luminescence (OSL) (see Chapters 3.3 and 7 and references therein) are increasingly common methods, frequently used to produce direct chronologies for ancient sediments. Due to the almost ubiquitous presence of sand within the fluvial deposits of the Solent region the most appropriate geochronological method is that of OSL. As the OSL technique can be carried out on both quartz and feldspar grains, which produce distinct luminescence signals, it can in effect provide two methods of producing ages for a sediment which contains both minerals. The OSL method is described in Chapter 3.3 below.

Unusually, there has also been an attempt to construct a chronological framework using the first appearance of specific artefact types in the Solent River system as tie-points (Westaway *et al*. 2006). In their scheme the first appearance of handaxes corresponds with MIS 15, assemblages with significant proportions of twisted ovate handaxes with MIS 11/10, the introduction of Levallois technology with MIS 9/8 and the arrival of *bout-coupé* handaxes with MIS 3. The method was critiqued by Ashton and Hosfield (2010), who point out that the Solent record of Levallois technology, a key tie-point used by Westaway *et al*. (2006), is small and contextually unclear. Furthermore their chronology for the first appearance of hominins is based on a reinterpretation of the Pakefield assemblage to MIS 15, rather than the more largely accepted MIS 17 (or late 19) attribution (Parfitt *et* al. 2005).

Gibbard (1985) argued persuasively that the most reliable method of correlating terrace deposits is to examine those deposits directly, comparing characteristics such as grain-size, sedimentary structures, lithology and heavy mineral content. In practice it may be the case that compromise must be reached between the scale of investigation (such as the large-scale correlation questions in the Solent River system) and the availability of sufficient lithostratigraphical data. This could be limited by, for example, physical access to *in situ* deposits or the preservation (or lack thereof) of suitably diagnostic characteristics within available deposits. Either situation will necessarily limit the possibility of correlating sediments by lithostratigraphical methods.

Due to the variability seen in the topography of both terrace and bedrock surfaces, it is arguable that a limited set of *in situ* stratigraphic data points is equally limiting in terms of generating robust correlative models if data are not representative of the terrace level in which they are located. The problem may be mitigated by the availability of a sufficient quantity of bedrock height and gravel thickness data that, while lacking lithostratigraphic detail, can be used in combination to indicate correlation of mapped landforms. If coverage is such that data points are numerous and closely-spaced, confidence may be increased.

2.3.3 Long profile projections

In regions where diagnostic lithological, biostratigraphical or chronological data are scarce, whether due to minimal variations in clast input into the fluvial system over time, preservation issues, or the availability of sedimentary exposures or datasets, terrace remnants may be correlated by means of altitudinal position along the river's palaeo-course (Briant *et al*. 2012). Such long profile correlations of terrace bodies are usually based on downstream projections of approximately straight or slightly concave upward gradients (Gibbard 1985; Briant *et al*. 2012). A recent case study examining the production of robust long profile correlations and terrace reconstructions (Briant *et al*. 2012) highlights a number of issues that can lead to alternative/contrasting interpretations of terrace stratigraphies depending on the conceptual and methodological approaches taken.

Conceptual approaches would include what data are used to describe or define terrace deposits, such as the modern terrace (i.e. ground) surface (e.g. Westaway *et* al. 2006) or the underlying sedimentary deposit thickness (e.g. Briant *et al*. 2012). The potential for post-depositional modification from solifluction/overburden addition, or reworking by stream erosion etc, will complicate the former approach. The latter approach may be affected by topographical variation in the palaeo-floodplain due to channelling or changing terrace thickness between the front and back of the outcrop. The choice of data used will also affect the volume of data available; terrace surfaces may be readily obtained from mapping data and provide more extensive geographical coverage while sedimentary data will be limited by the number of borehole records or fieldwork locations available.

As discussed below (2.4.2) conceptual and methodological approaches to correlating terrace fragments do vary between current stratigraphic models of the Solent River system. This has contributed to some of the differences between the models produced and arguably limits the robustness of those stratigraphic models, reducing confidence that can be placed in the long profile gradients produced.

2.4 Previous research of Solent River system

2.4.1 Previous research into the terrace stratigraphy of the Solent River system

The Solent River was first recognised by Darwin-Fox (1862), initiating 150 years of research on the region. Early work suggested either a marine (Codrington 1870) or fluvial (Evans 1864; Reid 1893) origin for the gravel terraces, or a combination of those factors as reviewed by Allen (1991). Geological memoirs in the late 19th/early 20th century (Reid 1898, 1899, 1902a, 1902b) and later studies (White 1915, 1917) recognised a fluvial origin for the gravels, although a substantial marine origin continued to be periodically proposed (Bury 1923; Everard 1952, 1954, 1956, 1957). Palaeolithic implements were soon recognised within the gravels and collected from the late 19th and early 20th Centuries onwards, although publication was sparse (Bury 1923, 1925; Burkitt *et al*. 1939; Calkin and Green 1949; Roe 1968; Shackley 1970; Wymer 1999). The first detailed study that focused on the terrace stratigraphy of the Solent River system was by Green (1936, 1943, 1946, 1947, 1950; Boswell and Green 1946; Calkin and Green 1949).

The concept of a Solent River system draining the Hampshire Basin (Darwin-Fox 1862) developed to include recognition of tributary deposits in the Test (Evans 1864; Strahan 1896), Itchen, Arun, Adur and Ouse (Strahan 1896), Frome (Reid 1899) and Avon (Reid 1902a). BGS Mineral Assessment Reports in the 1980s later classified many of the fluvial terraces in the region (Kubala 1980; Clarke 1981; Mathers 1982a, Mathers 1982b). Mapping in recent BGS memoirs (Edwards and Freshney 1987; Bristow *et al*. 1991; Hopson 2001; Booth 2002; Barton *et al.* 2003), in addition to the work of Green, provide the basis for current interpretations of the fluvial stratigraphy of the Solent River system (section 2.4.2 below). The various BGS studies are mapped independently using region-specific schemes, with no correlation between regions. Furthermore terrace altitudes are recorded relative to the modern river, counting levels up the valley side, making correlation between reports problematic. Particular issues arise with the stratigraphy of the River Test, as the deposits straddle the BGS map sheet for Winchester (299) and Southampton (315) as discussed in Chapter 5.

Recently, focus has returned to the issues surrounding the terrace stratigraphy of the Solent River system. Allen (1991; Allen and Gibbard 1993) correlated the terrace sequence by lithological and altitudinal analysis, defining the Solent as flowing eastward from the current River Frome (interpreted as following the course of the Palaeo-Upper Solent). The course continued through the now submerged valley north of the Isle of Wight before turning south to join the Channel River (Figure 2.13). Bridgland (1996) proposed the possibility of a progressive diversion of the upper Solent during the Pleistocene, after the Wight-Purbeck Chalk ridge was breached, capturing the head-waters of the Solent. It was thought that by the Middle Pleistocene the River Frome was draining southwards and was no longer part of the Solent River (Bridgland 1996, 2001). Velegrakis *et al*. (1999) identified southward-aligned valleys of the Frome-Piddle and Avon-Stour systems of Ipswichian-Devensian age, indicating that the breach occurred pre-MIS 5e, beheading the Solent River. The implication is that marine processes finally breached the Wight-Purbeck ridge from the south during the Ipswichian high sea-level stand (Antoine *et al*. 2003), with the Frome–Piddle and Avon-Stour subsequently flowing west of the Isle of Wight. Earlier significant denudation of the Wight-Purbeck ridge had resulted in the progressive loss of south-bank tributaries (Antoine *et al*. 2003). Westaway *et al*. (2006) modelled the progressive disruption of the Solent River system as initiating during the late MIS 6 warming limb. Upper Solent drainage diverted south through the Wight-Purbeck ridge, capturing the Solent head-waters, with the beheaded main Solent carrying only local drainage during the subsequent deposition of the Rook Cliff/St Leonard's Farm (Westaway *et al*. 2006) (Figure 2.13).

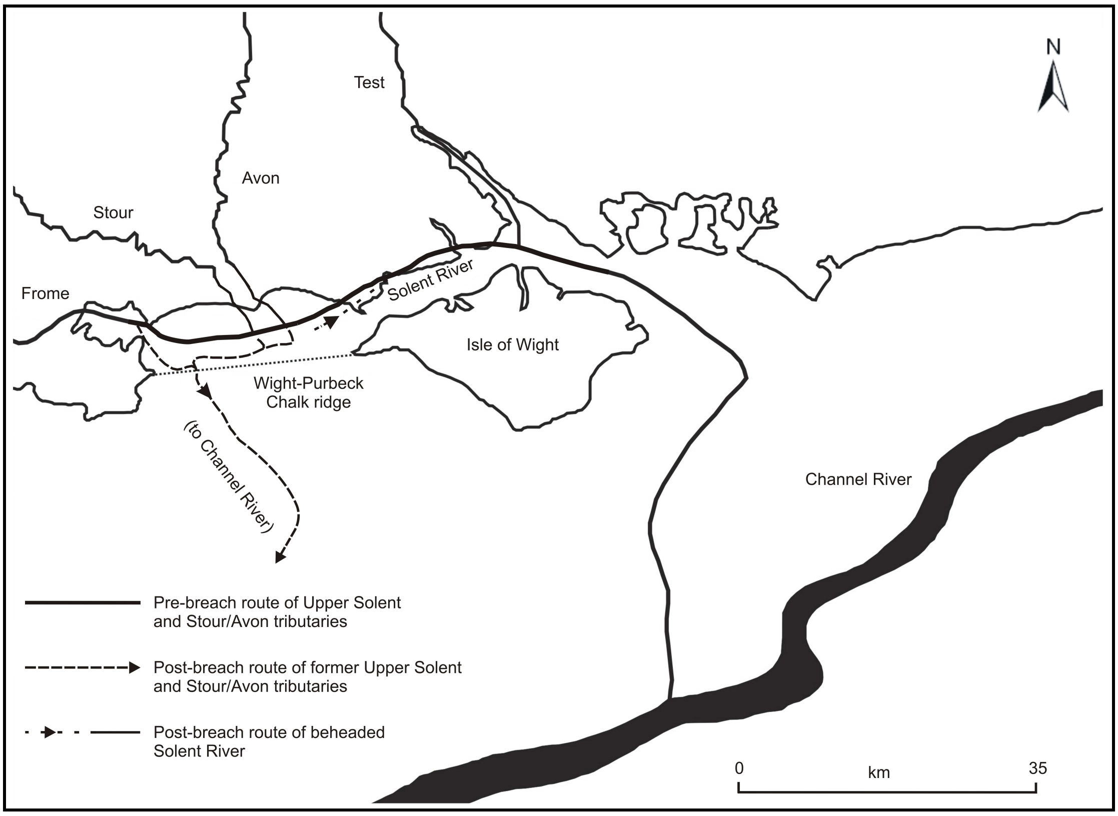


Figure 2.13. The Solent River and major tributaries during the low sea-level stand events of glacial periods, showing drainage routes before and after the breach of the Wight-Purbeck Chalk ridge (modified from Velegrakis *et al* (1999) with data from Westaway *et al*. 2006).

Interglacial deposits are typically not preserved in the Solent River system, being identified at just three sites in the lowest onshore terrace levels: at Pennington Marshes (Allen *et al.* 1996), Stone Point, Lepe (West and Sparks 1960; Brown *et al.* 1975; Green and Keen 1987; Briant *et al.* 2009c) and St Leonards Farm (Mathers 1982b; Briant *et al*. 2013). Allen and Gibbard (1993) attributed the warm-stage sediments of interbedded fossiliferous sands and silts in the Pennington and Lepe terraces to MIS 5e, which is supported by pollen analysis indicating pollen zone IpIIa at the former (Allen *et al.* 1996) and IpIIb at the latter (West and Sparks 1960). However, the location of the Pennington terrace upstream of, yet ~6 m lower than the Lepe terrace, led Allen *et al.* (1996) to propose a MIS 7 attribution for Lepe, a position supported by Bridgland (2001). None of the interglacial sediments at the three locations have produced biostratigraphically diagnostic fossil evidence. Recent OSL dating of the upper and lower gravels at Lepe (Bates *et al*. 2004; Briant *et al.*

2006) (see Tables 2.3 and 2.4 below) however indicates aggradation in MIS 4 and MIS 6 respectively, with the intervening interglacial sediments attributable to MIS 5e. Westaway *et al*. (2006) note both interpretations in their stratigraphic model (see below), preferring a correlation of the lower gravels at Pennington and Lepe (late MIS 6, see Table 2.3; their upper Rook Cliff/St Leonard's Farm gravel), with both interglacial sequences attributed to MIS 5e.

Recent studies, as described in the following section, have also attempted to address the stratigraphic and correlative interpretation of various elements of the Solent River system. These studies have centred on a variety of issues: interpreting the Pleistocene evolution of the Solent River system (Allen 1991; Allen and Gibbard 1993), modelling the uplift history of southern England (Westaway *et al*. 2006), correlating River Test terraces between BGS map sheets 315 (Southampton) and 299 (Winchester) (Bridgland and Harding 1987, Harding *et al.* 2012) and correlating the eastern Solent with the Sussex Raised beaches (the Palaeolithic Archaeology of the Sussex/ Hampshire Coastal Corridor project (PASHCC) (Bates *et al*. 2004, 2007; Bates and Briant 2009)). Each study, with some overlap of scope, has produced stratigraphic and/or correlative schemes of various elements of the Solent River system.

The archaeology of the Solent region is similarly receiving renewed focus (Bridgland and Harding 1987; Hosfield 1999, 2001, 2010; Wenban-Smith 2001; Hosfield *et al*. 2009; Ashton and Hosfield 2010; McNabb *et al* 2012; Davies 2013). A current reappraisal of the archaeology of the Solent River assessing human settlement history and technology (Davies 2013) will, alongside this study, provide a new contextual framework for the Palaeolithic record of the Solent River system.

The mapping and stratigraphic schemes of the current interpretations of the Solent River system are described in the following section and critiqued in detail in the relevant results chapter (Chapters 4, 5 and 6).

2.4.2 Current stratigraphic models of the Solent River system

Four recent reviews of the terrace stratigraphies in key areas of the Solent system have produced contrasting interpretive models of the fluvial sequences, due in large part to methodological and conceptual differences in approach. The work of Allen and Gibbard (1993; Allen 1991) was based on field observations, lithological interpretation and an unspecified dataset of borehole records from Mineral Assessment Reports (MAR) 50, 51, 103 and 122 (Kabula 1980; Clarke 1981; Mathers 1982a and 1982b respectively) and the BGS borehole archive. Gravel thickness envelopes were used to construct long profile projections of River Frome deposits between Wareham and Dorchester and Solent River deposits between Bournemouth and Southampton Water.

The Westaway *et al*. (2006) and Harding *et al.* (2012) models were based on terrace (i.e. ground) surface altitudes obtained from relating geological mapping to topography at a 1:25 000 scale and, where available, borehole records from the aforementioned Mineral Assessment Reports (i.e. around Fordingbridge (Hampshire) (MAR 50), north of Bournemouth (MAR 51), between Dorchester and Wareham (MAR 103) and around Lymington and Beaulieu (MAR 122); importantly excluding the Test Valley region). Long profile projections were constructed by Westaway *et al*. (2006) for the same River Frome and Solent River reaches as Allen and Gibbard (1993) above, the River Stour between Sturminster Marshall and Christchurch, the River Avon and the River Test (revised by Harding *et al.* 2012). Projection profiles were predominantly based on ground surface altitudes producing straight line gradients with limited gravel thickness data. Uplift modelling at key locations, with the appearance of certain Palaeolithic artefacts acting as tie-points, was used in their accompanying age model.

The PASHCC study was based on field observations, OSL dating, published test pits in Bridgland and Harding (1987) and 96 BGS boreholes. Mapping of the River Test deposits, based on gravel thickness envelopes, adapted the scheme of Edwards and Freshney (1987) while also extending the scheme north to BGS sheet 299 (previously mapped by Booth 2002). The result was a revised correlation of important terrace deposits in the Dunbridge area with those downstream at Warsash (see Chapter 4 for discussion).

Conceptual differences between the four schemes are apparent in terms of the data used to describe terrace deposits. The stratigraphical schemes produced by Allen and Gibbard (1993) and the PASHCC project are based on correlations of gravel thickness data while those of Westaway *et al.* (2006)/ Harding *et al.* (2012) use terrace surfaces. The method of constructing long profile correlations were therefore based on different, and not directly comparable, datasets.

Some of the most substantial differences between the stratigraphies of Allen and Gibbard (1993) and Westaway *et al.* (2006) occur within the Western Solent, defined here as the area between Christchurch Bay and Southampton Water (Figures 2.14 and 2.15). The Westaway *et al.* (2006) scheme rejects the gradients and correlations produced by Allen and Gibbard (1993), preferring to revert to the shallower gradients produced by the earlier work of Green (1946) and Mathers (1982b). Substantial re-attribution of terrace units and the introduction of a revised nomenclature were produced by the Westaway *et al*. (2006) study.

The terrace gradients produced by the Allen and Gibbard (1993) and Westaway *et al.* (2006) schemes will be assessed in Chapter 8 alongside those produced by this study.

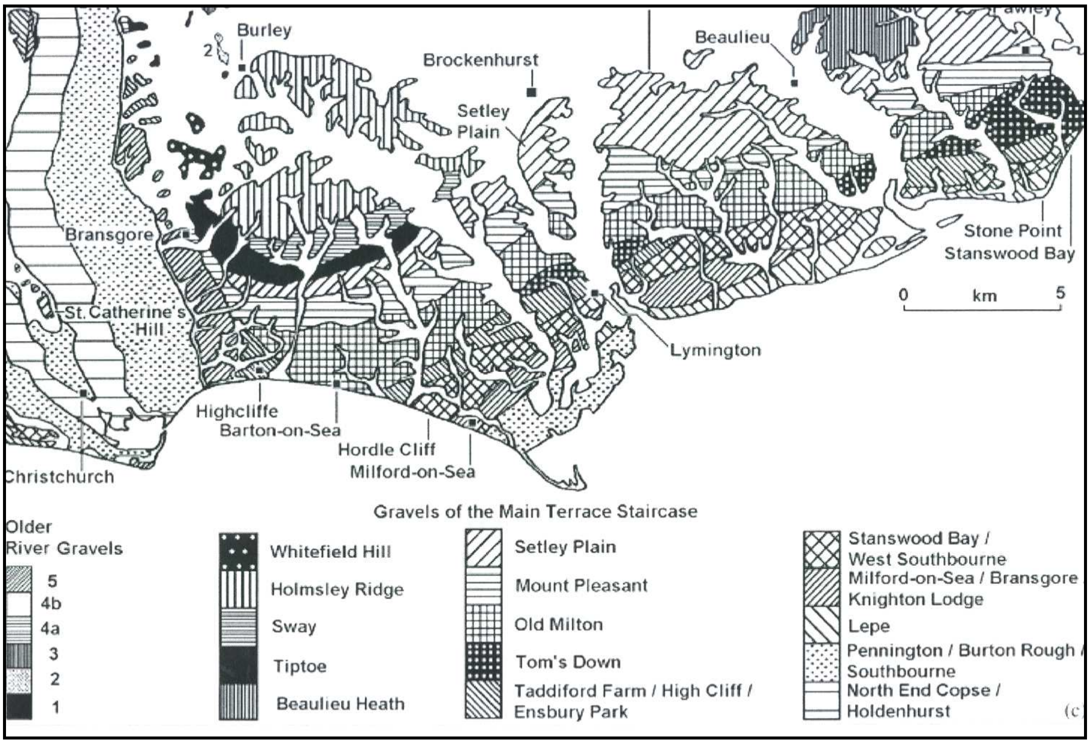


Figure 2.14. Western Solent mapping and stratigraphic model of Allen and Gibbard (1993; Allen 1991).

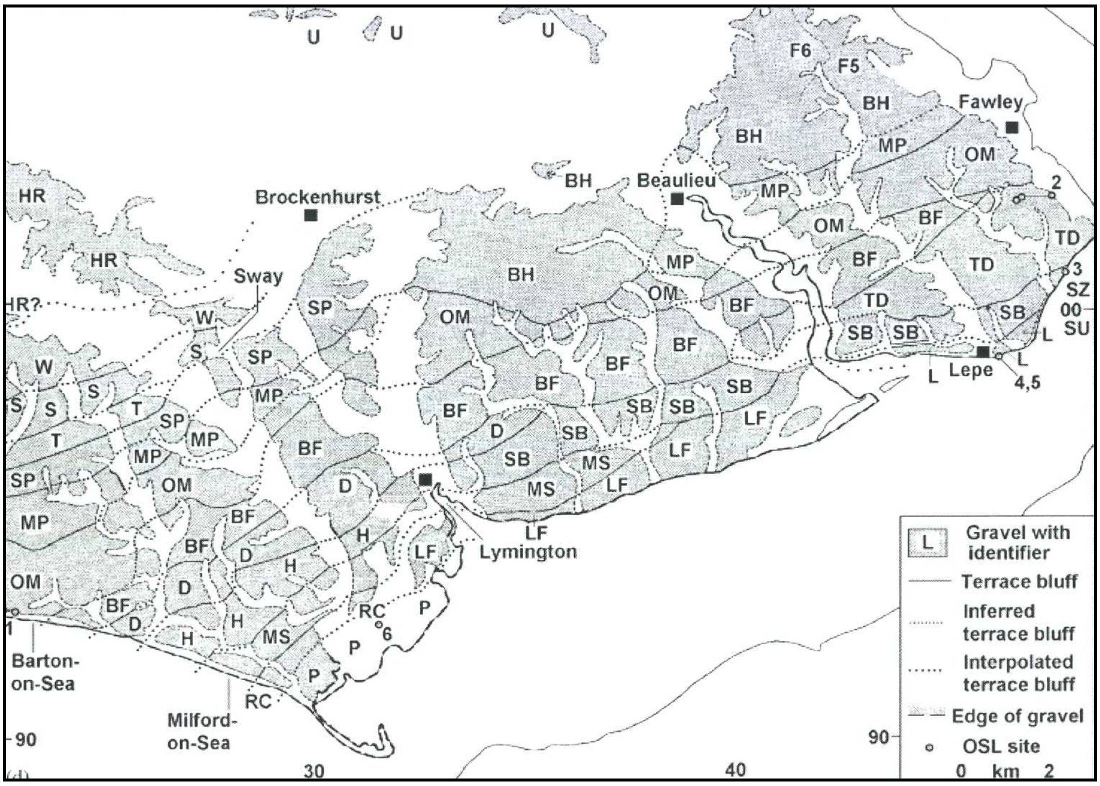


Figure 2.15. Western Solent mapping and stratigraphic model of Westaway *et al.* (2006). Key: BF Becton Farm; BH Beaulieu Heath; D Downton; H Hordle; HR Holmsley Ridge; L Lepe; LF St Leonards Farm; MP Mount Pleasant; MS Milford on Sea; OM Old Milton; P Pennington; RC Rook Cliff; S Sway; SB Stanswood Bay; SP Setley Plain; T Tiptoe; TD Tom’s Down; U Undifferentiated; W Wootton.

The orientation of the long profile projections generated by Westaway *et al*. (2006), based on the shallower gradients noted above, resulted in revised correlations of certain terrace bodies and a new stratigraphic scheme as outlined in Table 2.3. The differences between the Allen and Gibbard/Westaway *et al.* models across the Western Solent are complex and not easily summarised in a single table, as the revised mapping of the latter divides and reassigns a number of the former's mapped terraces. This is due to the diverse projection planes used which correlate terrace bodies differently as they progress downstream. Therefore each terrace (as defined by each model) is described and assessed in detail in the relevant results chapters below. For this study the Western Solent area has been divided into three regions; Region 1 (Stanswood Bay to the Beaulieu River), Region 2 (the Beaulieu River to the Lymington River) and Region 3 (the Lymington River to Christchurch Bay) to facilitate detailed analysis of the stratigraphic sequences as outlined in Chapter 5.

Table 2.3. Stratigraphic models and age attributions of Western Solent terraces relevant to the study (after Bates and Briant 2009) (cf. Tables 5.1, 5.5 and 5.9, Chapter 5).

Allen (1991) model		Westaway *et al.* (2006) model		Bridgland (1996, 2001) MIS	MIS based on OSL (Briant *et al.* 2006; Schwenninger *et al.* 2007)
Terrace	MIS	Terrace	MIS		
Setley Plain	?	Setley Plain/ Beaulieu Heath	13b	13	-
Mount Pleasant	?	Mount Pleasant	12	12	-
Old Milton	?	Old Milton	10	11	-
		Ensbury Park/ Becton Farm	9b		
Tom's Down	?	Downton/ Tom's Down	8	10	9-8
Taddiford Farm	?			9	8-7e
Stanswood Bay	?	Hordle/ Stanswood Bay	7b	8	8-7b
Milford-on-Sea	?	Milford-on-Sea	6	?7b-e	-
Lepe (lower)	Pre- 7	Rook Cliff/ St Leonard's Farm (lower) or Lepe	Late 6	?7b-e	7d-6
Stone Point, Lepe	7	Stone Point, Lepe	5e	7a	5e
Lepe (upper)	6	Rook Cliff/ St Leonard's Farm (upper) or Lepe	5d-2	6	5d-3
Pennington (lower)	6	Rook Cliff/ St Leonard's Farm (lower) or Pennington	Late 6	6	-
Pennington Marshes	5e	Pennington Marshes	5e	5e	5e
Pennington (upper)	5d-2	Rook Cliff/ St Leonard's Farm (upper) or Pennington	5d-2	5d-2	5d-3

Westaway *et al*. (2006) also produced a revised correlative scheme for the River Test, proposing that Terrace 4 in the Dunbridge area (as mapped by Booth 2002) correlates with Terrace 3 in the Warsash area (as mapped by Edwards and Freshney 1987). However the long profile projection produced by Westaway *et al*. (2006) for the Test sequence erroneously placed the archaeologically important gravel pits in Terrace 3 at Warsash at ~25m O.D., around 10 m too high (Ashton and Hosfield 2010). Early fieldwork for this study conducted at Warsash (see Chapter 4 below) confirmed ground level in the area to be ~16.5m O.D., with bedrock contact at Warsash Common and Hamble Park (nearby former quarry locations) at ~11.5m. In conjunction with borehole records around Warsash, analysis indicated the presence of two distinct terrace levels in Edwards and Freshney's (1987) Terrace 3 (Hatch 2011). This was also addressed by Harding *et al*. (2012) as discussed in Chapter 4. The revised Test stratigraphy proposed by Harding *et al.* (2012) (Figure 2.16) shows some changed correlations to those of the PASHCC project (Figure 2.17), which largely endorsed the scheme of Edwards and Freshney (1987) while extending the model into map sheet 315. The chronology of the Test sequence was also adjusted by Harding *et al*. (2012) from that of Westaway *et al.* (2006) based on the modelled start of uplift in the region. The PASHCC project has also contributed a substantial OSL dating programme with some success (Bates *et al*. 2004, 2010; Briant *et al*. 2006, 2009b and 2009c; Schwenninger *et al.* 2007; Briant *et al*. 2012) (Table 2.4), but as discussed in Chapter 7 (Geochronology) confidence is limited in those dates produced above the Stanswood Bay terrace in the Western Solent and above Terrace 2 of the Test (Bates and Briant 2009).

Broader problems exist in understanding the fluvial stratigraphy of the Solent region. The extensive staircase of terraces appears to show that terrace formation may have been more frequent than a single downcutting episode per glacial-interglacial cycle, based on Bridgland's (2001) proposed correlation of the Mount Pleasant terrace with deposits of the Goodwood/Slindon Raised Beach (Table 2.3), and the OSL dates produced by PASHCC. Indeed the stretch of the Western Solent between Bournemouth and Southampton Water is thought to have more Middle Pleistocene terraces than any other river in Britain (Bridgland 2001).

Issues remain to be resolved if the archaeological record of the Solent River system is to be more fully understood. Principal amongst these are correlation of terraces within and between the River Test, the Solent River and the River Stour, and the chronology of fluvial deposition across the system. Reassessment of the terrace stratigraphies of the Test Valley, Western Solent and Bournemouth study areas (Chapters 4, 5 and 6 respectively) will be combined with interpretation of the correlation between the three areas in order to provide a more robust contextual framework for the archaeology of the Solent River system.

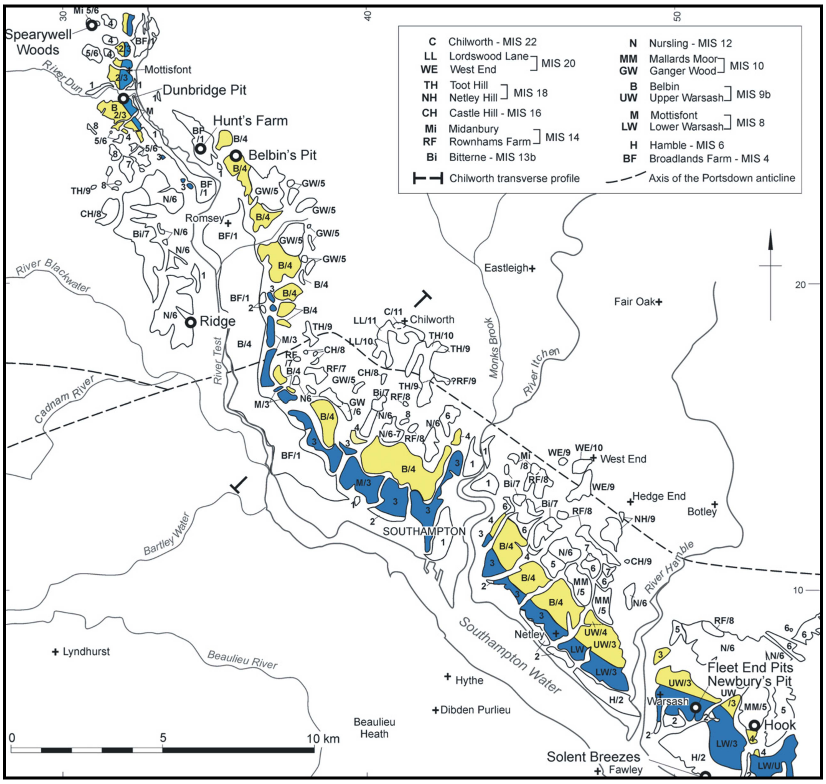


Figure 2.16. River Test mapping and stratigraphic model of Westaway *et al.* 2006, updated in the Warsash area by Harding *et al.* 2012.

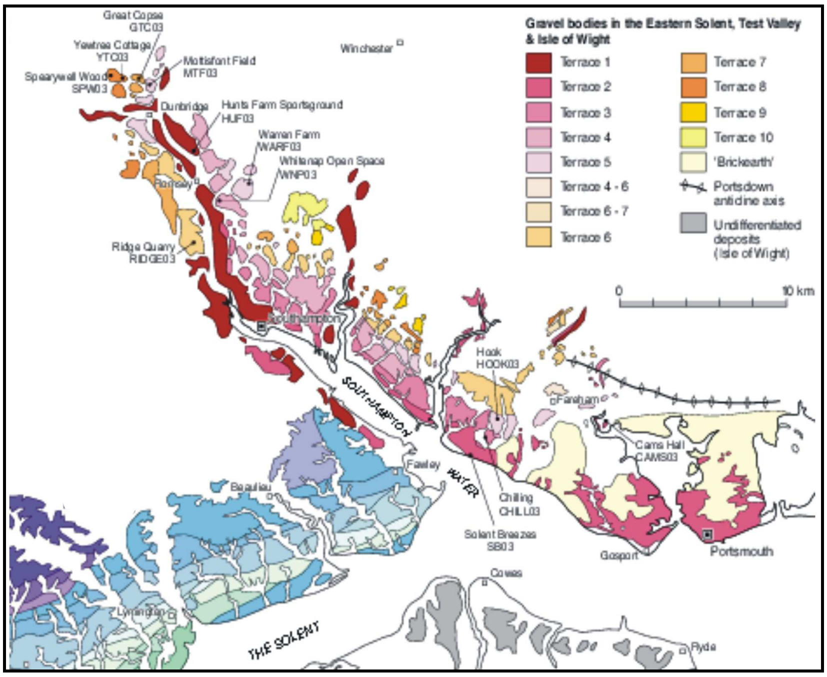


Figure 2.17. River Test mapping and stratigraphic model of the PASHCC project (Briant *et al.* 2012; after Edwards and Freshney 1987).

Table 2.4. OSL dates from the Solent Region. OSL dates: **n** – dates used to calculate the weighted mean, *n* – outlier; (σ sigma); [1]near the bluff bounding the older Mount Pleasant Gravel (Allen and Gibbard 1993) or Old Milton Gravel (Westaway *et al*. 2006); [2]near the bluff in the older Tom's Down Gravel.

Site	Gravel	Age(ka)	Weighted Mean	MIS (range)	Source
Barton-on-Sea	Old Milton (Western Solent)	**288±82 (±2σ)** **355±46 (±2σ)** **384±68 (±2σ)** *648±130 (±2σ)*	351±35 (±2σ)	10 (11-9)	Briant *et al*. 2006
Badminston Farm, Fawley	Tom's Down[1] (Western Solent)	**306±62 (±2σ)** **337±46 (±2σ)** **341±78 (±2σ)** *554±218 (±2σ)* *568±164 (±2σ)*	329±33 (±2σ)	9 (11-8)	Briant *et al*. 2006
Exbury	Taddiford Farm (Western Solent)	**254±18 (±2σ)**	-	8 (8-7e)	Schwenninger *et al.* 2007
Stanswood Bay	Stanswood Bay[2] (Western Solent)	**238±38 (±2σ)** **244±26 (±2σ)** **246±36 (±2σ)** **246±38 (±2σ)** **253±42 (±2σ)**	245±15 (±2σ)	8 (8-7b)	Briant *et al*. 2006
Lepe	Lepe Lower Gravel (Western Solent)	**130±24 (±2σ)** **156±26 (±2σ)** **161±22 (±2σ)** *198±30 (±2σ)*	149±14 (±2σ)	6 (6)	Briant *et al*. 2006
Lepe	Lepe Upper Gravel (Western Solent)	**65±14 (±2σ)**	-	4 (5a-3)	Briant *et al*. 2006
Pennington Quarry	Pennington Upper Gravel (Western Solent)	**34±9 (±2σ)** **67±22 (±2σ)** *94±22 (±2σ)*	46±8 (±2σ)	3 (3)	Briant *et al*. 2006
Yewtree Cottage	Terrace 8 (Test)	**>200**	-	> 7	Bates *et al.* 2004; Briant *et al*. 2012
Ridge	Terrace 6 (Test)	**413±26 (±1σ)** **280±19 (±1σ)**	-	11 (12-11) 8 (8)	Bates *et al.* 2004; Briant *et al*. 2012
Hook	Terrace 5 (Test)	**233±37 (±1σ)** **292±20 (±1σ)**	-	7d (8-7a) 8 (9-8)	Bates *et al.* 2004; Briant *et al*. 2012
Dunbridge	Mottisfont/ Terrace 3 (Test)	**283±26 (±1σ)** **310±51 (±1σ)** **262±43 (±1σ)** **341±29 (±1σ)** **302±21 (±1σ)** **335±45 (±1σ)**	305 ±25 (±2σ)	9 (9-8)	Harding *et al.* 2012
Chilling Copse	Brickearth over Terrace 3 (Test)	**29±2.3 (±1σ)**	3	3 (3-2)	
Solent Breezes	Terrace 2 (Test)	**212±25 (±1σ)** **204±17 (±1σ)** **231±24 (±1σ)** **221±20 (±1σ)**	217±22 (±1σ)	7 (8-6)	Bates *et al.* 2004; Briant *et al*. 2012
Hunts Farm sports ground	Terrace 1 (Test)	**69±5**	-	4 (5a-4)	Bates *et al.* 2004; Briant *et al*. 2012

CHAPTER THREE: METHODS

In order to achieve the aims of the study the following methods were employed, focused on producing additional and complementary data to that utilised in current stratigraphic schemes of the Solent River system. The available borehole record from the region was analysed, sedimentological data from excavated quarry sections and exposed coastal sections was recorded, OSL dating was employed on samples of fluvial sands collected from the region and GPR surveys were conducted at various locations. In order to integrate data from boreholes, sections and GPR surveys a method was developed to create 'synthetic boreholes' which were used in long profile projections of fluvial terraces. The data was visualised and analysed by use of ArcGIS and RockWorks software. This chapter will describe the methodological approach for each technique, how samples and/or data were collected, and by what means terrace mapping, long profile projections and terrace gradients were generated and analysed. Datasets are arranged around the borehole log format as the common framework for use in the subdivision of terrace stratigraphies and the generation of long profile projections. The density of borehole coverage also played a role in dictating the location of fieldwork sites (see Chapters 4, 5 and 6).

3.1 Borehole records

Borehole records from the Solent River system region provided a substantial data source during this study. In total 666 borehole logs across the region were used from those collected from the British Geological Survey (BGS) archive, comprising 288 from the Test Valley, 226 from the Western Solent and 152 from the Bournemouth region. In particular borehole records were useful in providing extensive data on gravel deposit and/or terrace unit thickness (dependent on the sedimentological detail recorded in the log) and the location and elevation of the bedrock surface (cf. data used in the Allen and Gibbard (1996) and Westaway *et al.* (2006) methods as discussed in 2.4.2 and Chapter 8).

The locations of the boreholes that are situated on fluvial terraces in the Solent River system study area can be seen in Figure 3.1. This significant archive was of importance in a number of ways, as the data generated from examining borehole records contributed to: the location of fieldwork sites, interpretations of mapped terrace extents, the construction of terrace long profile and cross-section gradients and terrace correlations within the various elements of the Solent River system.

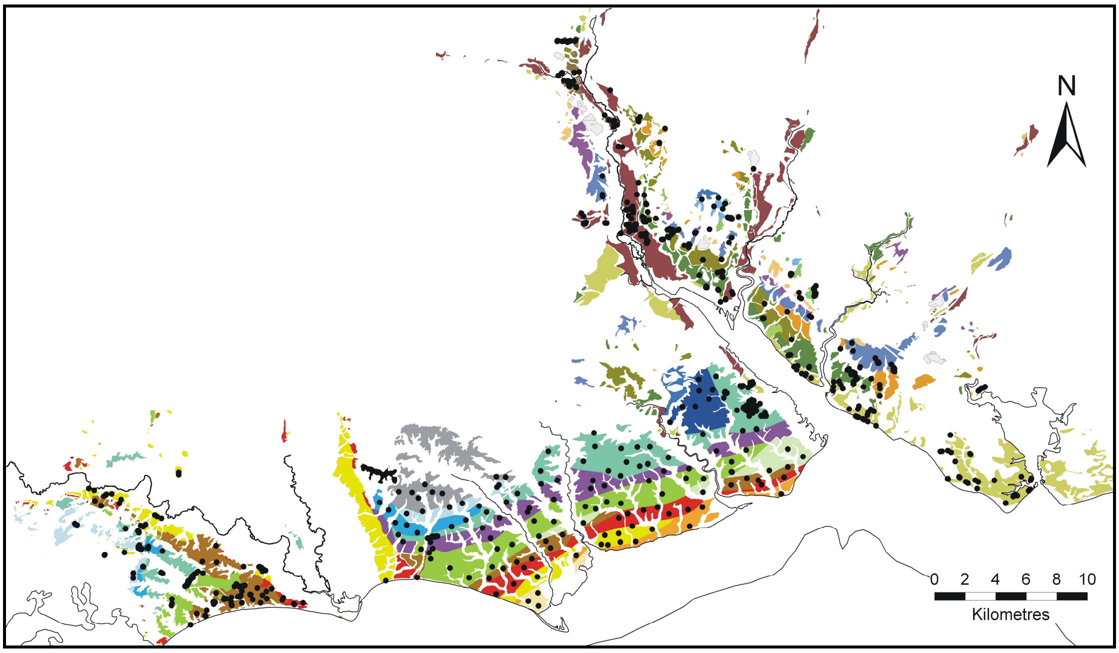


Figure 3.1. Borehole locations situated on fluvial terraces within the Solent River system. The various stratigraphic schemes are described in Chapter 2.4.2 (Figures 2.13, 2.14 2.15 and 2.16) and Chapters 4, 5 and 6.

3.1.1 Borehole selection criteria

Borehole records were collected from locations within the study area then mapped with gravel terrace deposits in BGS memoirs and geological mapping via examination of the ArcGIS model (3.6.1 below). Criteria for borehole records to be included in the study were: accurate National Grid Reference (NGR) location data, ideally ±10 m although ±100 m accuracy was also accepted as each borehole was to be individually assessed in terms of proximity to terrace bluffs or transitions (see 3.6.2 below); recorded elevation (O.D.) data; the presence of fluvial gravel terrace aggradations as determined by sedimentological description; and clear contact of the terrace deposits with the underlying bedrock.

3.1.2 Borehole data acquisition and selection

The BGS collates and archives borehole records, maps and other ancillary data produced from boreholes sunk in the process of mapping for regional mineral assessment surveys and construction of geological maps. In addition, the archive includes boreholes sunk for site investigation ahead of infrastructural construction works. The BGS also stores some commercial records, although these are often not available publicly due to confidentiality agreements.

Records were initially obtained during visits to the BGS at Keyworth, Nottingham, accessed via the internal digital data storage system which the BGS maintains. The borehole record resource was then made available, and was thereafter accessed, online (http://mapapps2.bgs.ac.uk/geoindex/home.html).

Borehole records were identified by use of the reference assigned by the BGS, which was based on individual numbering within quartered (i.e. NW, NE, SW and SE) 10 km grid squares (e.g. SU30 SE6). Records were initially assessed in terms of the requirements set out in the selection criteria above. After ensuring sufficient geographical data (location and elevation), an assessment was made of the recorded sedimentary characteristics of deposits. Some borehole records, particularly those from mineral assessment reports, contained detailed sedimentary descriptions and/or interpretations of a sediment's origin. Other records were far less detailed, sometimes simply recording a deposit as, for example, ‘gravel’.

Some borehole records showed gravels directly underlying substantial deposits of made ground and as such it could not be ascertained how representative the recorded gravel thickness was of the original thickness of the gravel body. The amount of any potential modification of the terrace surface was therefore unquantifiable, and this was taken into account when assessing the borehole record in later long profile correlations. Data pertaining to depth to bedrock surface was still included in the study. The issue of terrace surface modification was important in assessing each sedimentological/stratigraphic record in the study and also in assessing current stratigraphic schemes of terrace long profiles as discussed in Chapters 2.3, 2.4 and 8.

3.1.3 Borehole data analysis

The borehole data that passed the selection criteria were entered into Microsoft Excel spreadsheets. These were divided into the same 10 km grid squares as OS mapping in the study area in order to facilitate data storage and analysis/interpretation. These borehole datasets were then entered into ESRI ArcGIS 9.2, a Geographic Information System that consists of a suite of integrated applications that enable the mapping, analysis, data management and visualization of geographical data (see 3.6.1 below). ArcGIS enabled the integration of collected borehole datasets with Ordnance Survey maps, topographical data and BGS geological mapping of the study area.

The production of long profile projections of terrace deposits from borehole data is described in 3.6 below. The specific details for the location of terrace long profiles and cross sections are outlined in Chapters 4, 5 and 6.

3.2 Description and analysis of fluvial sediments and stratigraphy

3.2.1 Site selection criteria

The location of sites for excavation, section recording and sampling was focused on areas that lacked borehole coverage and/or could contribute to addressing specific research questions. Particular issues that could be investigated by targeted fieldwork were correlation of terrace deposits and terrace landforms within or between elements of the Solent River system, the stratigraphic context of significant archaeological find-spots, and locating appropriate sediments for OSL dating. The rationale for each individual section is described in the results chapters. The selection of fieldwork locations was also partly dictated by access to available exposures or sites. Section recording was carried out in disused quarry locations and coastal sites in the study area where relevant permissions could be obtained.

3.2.2 Physical description of sediments

Each location examined was assigned a site code, incorporating the site name, year of investigation and section/log number. The precise location and elevation data was obtained either by use of a differential GPS (Global Positioning System) or through surveying with a total station. Where the latter was undertaken, elevation and location data was transferred from Ordnance Survey benchmarks and nearby mapped features (e.g. building or boundary locations). Sedimentary profiles were recorded in vertical sections where exposure allowed or as logs. Coastal exposures were cleaned prior to description in order to remove the weathered surface and quarry sections to be recorded were excavated by hand. Sections were drawn and photographed before being described in terms of sediment composition, grain size, colour, clast size/shape, sorting, inclusions (including post-depositional staining), facies type and sedimentary structures. Contacts between beds and with the bedrock were also described. Where there was insufficient access to expose extensive sections of sediments, particularly at coastal sections, vertical logs were recorded with as much sedimentary detail as possible.

Sedimentary interpretations follow Miall's (1977, 1996) lithofacies analysis approach as modified by Briant (2002) (Tables 3.1, 3.2 and 3.3). The approach is characterised by changes in scale, as interpretations of fluvial styles are produced from amalgamations of data from a range of analyses. Lithofacies codes (Table 3.1) are applied to beds based on descriptions of sediment bodies. Lithofacies associations are typical groupings of recurring and therefore genetically-linked lithofacies based on variations in sedimentary features and erosional boundaries. Bounding surfaces (Table 3.2) describe the form of surfaces/contacts between lithofacies or lithofacies associations, and can be arranged into a hierarchy of classification based on scale. They then identify the significance of changes between lithofacies or lithofacies associations. Architectural elements (Table 3.3) are building blocks of a succession, made from sedimentary groupings of lithofacies associations or bounding surfaces. Assemblages of lithofacies combinations, bounding surfaces and their geometry are indicative of architectural elements. Alluvial architecture is defined by collections of architectural elements and their three-dimensional geometry, proportion, and spatial distribution.

Table 3.1. Lithofacies nomenclature (Briant 2002, after Miall 1977, 1996).

Facies code	Lithofacies	Sedimentary structures	Geometry (if appropriate)	Interpretation
Dmm	Matrix-supported, massive	Structureless mud/sand/pebble mixture		Debris flow
Gmm	Matrix-supported massive gravel	Massive		Debris flow
Gcm	Clast-supported massive gravel	Massive		Debris flow or (if associated with involutions and wedge forms) periglacial disturbance
Gh	Clast-supported, crudely bedded gravel	Horizontal bedding, imbrication		Bedload transport, large-scale bedforms
Gt	Gravel, stratified	Trough cross-beds	In rectangular beds, shape independent of sedimentary structures	3-D bedform migration (curved crested dunes)
Gp	Gravel, stratified	Planar cross-beds	Extensive beds	2-D bedform migration
			Lens or 'channel' forms	Bar-top slough-channel (Bryant, 1983b)
Gs	Gravel, stratified	Broad, asymmetric scours, crude cross-bedding aligned with base (N.B. included in Miall's Gt category)	In beds with concave-upward lower contacts, shape dependent on sedimentary structures	Cut-and-fill event. Composite infilling possibly represents longer duration. N.B. similar to architectural element HO
Gl	Clast-supported gravel, stratified	Low-angle (<15°) cross-beds		Horizontal bedding on an inclined surface or (where laterally associated with Gh) part of a bar-form
Ss	Sand, fine to coarse, may be pebbly	Broad, shallow scours, may be crudely cross-bedded, lag material common	Dependent on sedimentary structures	Cut-and-fill event as Gs.
St	Sand, fine to coarse, may be pebbly	Solitary or grouped trough cross-beds		3-D dune migration
Sp	Sand, fine to coarse, may be pebbly	Solitary or grouped planar cross-beds	Extensive beds	2-D bedform migration
			Lens or 'channel' forms	Bar-top slough-channel (Bryant, 1983b)
Sr	Sand, fine to coarse	Ripple cross-lamination		Ripples
Sh	Sand, fine to coarse, may be pebbly	Horizontal lamination		Plane-bed flow (frequently in bar-top location – Bryant, 1983b)
Sm	Sand, fine to coarse	Massive, or faint lamination		Gravity flow deposit, or bedding not preserved
Fl	Sand, silt, mud	Massive, or faint lamination		Overbank, abandoned channel or waning flood deposits
Fsm	Silt, mud	Massive		Overbank, abandoned channel or waning flood deposits

Table 3.2. Hierarchical classification of bounding surfaces (Briant 2002, after Miall 1977, 1996).

Order	Example	Significance
First	Cross-bed set	Virtually continuous, no significant erosion
Second	Different co-sets	Short-term change in flow conditions or direction, but no significant time break
Third	Cross-cutting surfaces within macroforms	Medium-scale shift in flow direction or strength
Fourth	Basal scours of minor channels	Shift of small-scale form in system
Fifth	Bounding major beds such as channel-fill complexes, related to palaeosols	Channel migration / shifting
Sixth	Groups of channels or palaeovalleys	Significant change of fluvial regime
Seventh	Around a whole alluvial fan body	Discrete allogenic events

Table 3.3 Definition of architectural elements in fluvial deposits (Briant 2002, after Miall 1977, 1996).

Element	Symbol	Principal facies assemblage	Geometry and relationships
Channels	CH	Any combination	Finger, lens or sheet; concave-up erosional base; internal concave-up 3rd-order erosional surfaces common
Gravel bars and bedforms	GB	Gh, Gp, Gs, Gl	Lens, blanket; commonly interbedded with SB
Sandy bedforms	SB	St, Sp, Sh, Sr	Lens, sheet, blanket, wedge; occurs as channel fills, crevasse splays, minor bars
Downstream-accretion macroform	DA	St, Sp, Sh, Sr	Lens resting on flat or channelled base, with convex-up 3rd-order internal erosion surfaces and upper 4th-order bounding surface
Lateral-accretion macroform	LA	St, Sp, Sh, less commonly Gh, Gt, Gp	Wedge, sheet, lobe; characterised by internal lateral-accretion 3rd-order surfaces
Scour hollows	HO	Gh, Gs, Ss	Scoop-shaped hollow with asymmetric fill
Sediment gravity flows	SG	Dmm, Gmm, Gmg, Gci, Gcm	Lobe, sheet, typically interbedded with GB
Laminated sand sheet	LS	Sh, minor Sp, Sr	Sheet, blanket
Overbank fines	FF	Fm, Fl	Thin to thick blankets; commonly interbedded with SB; may fill abandoned channels

3.2.3 Coastal section recording

Stratigraphic data was also collected by means of extensive coastal surveys. During the study several coastal sections which were physically out of reach were surveyed using a Topcon Imaging Station (IS). Section faces were scanned by means of automated reflectorless surveys, where user-defined areas of a vertical surface are measured by the IS laser. Sections were between 20 m and 110 m in length, dependent on where vegetation cover or sediment slumping obscured sedimentary detail. Scanning was conducted by continuous horizontal measurement at 10 cm vertical steps.

Topcon Image Master software was used to generate three-dimensional models from the acquired survey data, consisting of textured representations of the surveyed elevation. Polylines were then manually produced defining bedrock surface, gravel thickness and ground level, with each point along the polyline generating location (easting and northing) and altitude (m O.D.) data. Photographs taken at section locations were used to aid the interpretation of sedimentary boundaries and/or surfaces as these were often found to be clearer and more detailed than the images produced by the in-built IS camera. While not obtaining the level of detail to easily differentiate sedimentary beds, i.e. 2nd and 3rd order surfaces, extensive bedrock elevation and terrace thickness data was obtained. It was also possible to identify 4th and 5th order surfaces, those relating to channel scours and channel-fill complexes.

The data acquired by IS surveying of coastal sections was complementary in scale to the more detailed sedimentary descriptions obtained from quarry section exposures (3.2.2 above). The strengths of the IS survey method were that substantial sedimentary datasets (tens of metres) could be obtained for a coastal section relatively quickly when compared to exposing and recording quarry sections. The weakness of the method was that sedimentary detail was limited largely to major architectural elements with substantial bounding surfaces. The scale of the aims and objectives of the present study, focused on stratigraphic sequences and correlations, is more appropriate to the use of the method than studies examining sedimentary detail more closely. The extensive linear data generated by IS surveying of coastal sections were used to generate synthetic borehole logs as described in 3.6 below.

3.3 Optically Stimulated Luminescence (OSL) dating

3.3.1 The OSL method

The OSL technique, when applied to the naturally occurring minerals of quartz (qz) and feldspar (fs) often found in fluvial sediments, can determine the amount of time that has passed since the sediment was last exposed to sunlight. This is because such minerals act as dosimeters, recording their interaction with radioactive elements during burial by storing a portion of the energy they are subjected to. The process is only interrupted (in the case of optically rather than thermally stimulated luminescence) when the mineral is next exposed to a light source and a portion of the accumulated energy is released in the form of light. The OSL method is designed to stimulate and then measure the released signal (known as the palaeodose or equivalent dose (D_e)) (Chapter 3.3.4), which in conjunction with the rate of isotope uptake per year a sample has been exposed to (the dose rate) will provide an age for the sample (Chapter 3.3.6).

The initial development of luminescence methods for dating sediments began with thermoluminescence (Wintle and Huntley 1979, 1980; Wintle 1980), after which the principles of OSL were first applied to quartz in fluvial sediments by Huntley *et al.* (1985). Recent reviews of the method are provided by Wallinga (2002), Duller (2004) and Preusser (2008), and the basic principles are summarised here before more detailed discussion below. Upon deposition, sediment is bombarded by various radioactive elements in the environment: alpha (α) particles, beta (β) particles and gamma (γ) rays, naturally occurring as radioactive isotopes of uranium (U), thorium (Th) and potassium (K) in the surrounding sediment, in addition to cosmic rays. Each element can travel different distances through a sediment - alpha particles only a few hundredths of a millimetre, beta particles a few millimetres and gamma rays up to around 30 cm. Some cosmic rays penetrate the Earth’s atmosphere and enter the subsurface, although the radiation dose delivered decreases with depth and varies with altitude, longitude and latitude. The interaction of such radiation (i.e. ionization) with a quartz or feldspar grain provides energy to electrons within the mineral’s electronic band structure - the range of energy bands that an electron may inhabit (Figure 3.2). Electrons within the valence band are bound to individual atoms and are usually stable. Ionization can push electrons into the conduction band, a higher energy state within the crystal lattice of the mineral (Figure 3.2 (i)). Some electrons will then become trapped at defect sites within the lattice framework of the qz or fs mineral, known as trapping centres (T_1 & T_2 in Figure 3.2 (ii)). Trapping centres of increasing depth below the conduction band are more stable, allowing electrons to be stored in such a state for hundreds of thousands of years. The application of sufficient heat or light to the mineral will release trapped electrons which recombine with holes at luminescence centres (vacated by other electrons earlier in the process) within the band gap between the conduction and valence bands (L in Figure 3.2 (iii)). Energy lost by the release of such trapped electrons will be emitted by light photons, producing a (measurable) luminescence signal.

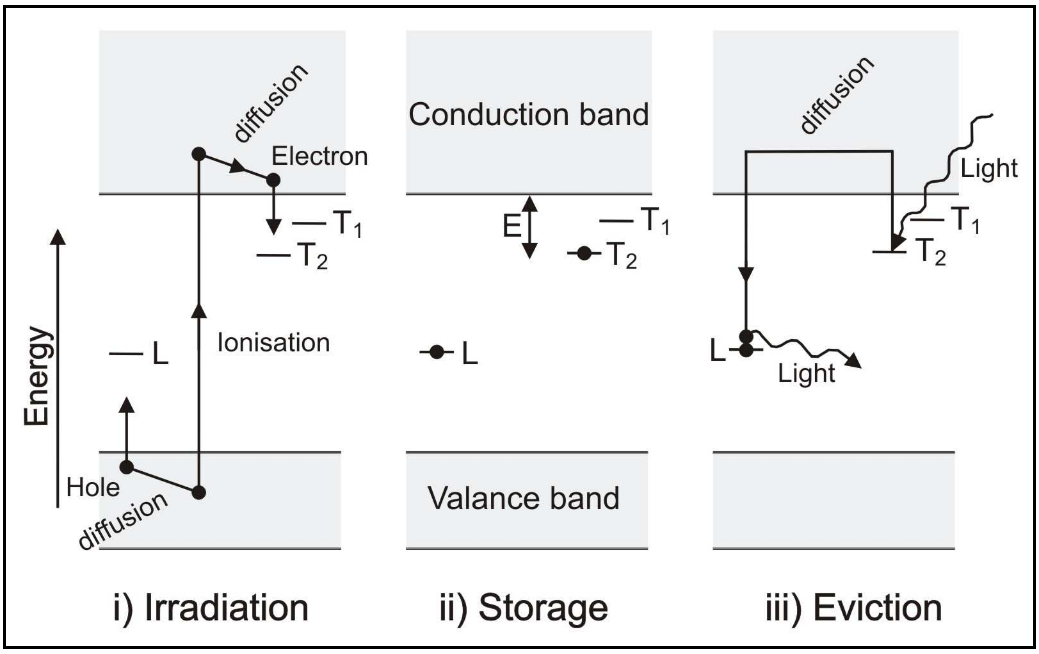


Figure 3.2. Energy level diagram illustrating the luminescence process (Redrawn from Duller 2008, modified from Aitken 1990).

The accumulation of electrons stored within these minerals is proportional to the length of time that a sediment has been buried, i.e. it is a measurable record of when the sediment was last exposed to sunlight. In terms of fluvial deposits the OSL technique will determine when aggradation occurred and therefore provide a chronology for the deposition of artefacts contained within the gravel terrace. The method will provide a minimum age of when archaeological artefacts became incorporated into the aggraded floodplain fluvial sediment.

There are, however, a number of potential issues which could produce inaccurate OSL dates that have to be tested for. The potential for erosion and transportation of sediments, which can re-expose a sediment to light and so reset the start point of the accumulation of isotopes (giving a second ‘zeroing’ event) can, if undetected, lead to age underestimation. Furthermore, care has to be exercised to ensure that protocols produce responses from stable electron traps to ensure that the resulting luminescence signal corresponds to the length of deposition (Murray and Wintle 2000). Partial bleaching, where electron traps are not fully emptied prior to deposition, can lead to an age over-estimation due to the inclusion of a residual signal (Chapter 3.3.6).

3.3.2 Sampling

OSL samples were taken from fluvial sand deposits exposed in former quarries and coastal sections during fieldwork. The choice of which sand deposit to sample within a section was based on a number of criteria: an interpretation that the sand lens/bed was of fluvial origin (e.g. the presence of interbedded sands and gravels, presence of sorted gravels, identifiable bedding structures in sands etc); homogenous sand lenses with little or no inclusions, iron-staining or post-depositional disturbance (in order to reduce the possibility of further radioactive elements affecting the accumulated dose of the sediment, see below); sand lenses of sufficient thickness (at least a 30 cm radius of sediment around the sampling area in order to incorporate all of the gamma radiation the sample will have been exposed to). The rationale for each individual sample location is described in the results chapters.

Sediment samples were taken in the field within opaque plastic tubing, sealed at the outer end and driven into exposed section faces. Upon removal from the section tubes were sealed at the other end to prevent light penetration and stored and transported in light-tight bags. Further (non light-sensitive) samples were then taken from the sediment around the tube locations for water-content and isotope analysis. 100 mg samples were taken to measure concentrations of uranium (U) and thorium (Th) (by Inductively Coupled Plasma-Mass Spectrometry (ICP-MS)) and potassium (K) (by Inductively Coupled Plasma-Optical Emission Spectrometry (ICP-OES)), carried out at the Scottish Universities Environmental Research Centre (SUERC). These isotope concentrations contribute to the determination of the overall dose rate that a sediment has been exposed to over time as described above. *In situ* measurements of the isotope concentrations at each samples' location was also carried out by use of a gamma spectrometer, which measures a sphere with a diameter of 30 cm. After removal of the pair of sample tubes from the sand lens a >30 cm deep hole was hand-augured into the section face to receive the spectrometer probe. Measurement was then taken for a minimum of 45 minutes.

The section was also drawn, recorded and photographed, with the location of both the section face and the OSL sample(s) surveyed by Total Station. OSL samples were then taken to the luminescence lab at Queen Mary University of London for analysis.

3.3.3 Laboratory preparation

Samples were stored and processed in a light-tight laboratory under controlled red lighting conditions. Upon opening a sample, the ends of each (2-3cm) were discarded due to the possibility of accidental exposure to sunlight during sampling in the field. Tube ends were used as an extra sample for analysis of water-content. Water-content calculation was carried out by weighing each sample before completely drying them and re-weighing.

After completely drying the contents of each tube, samples were separated into fractions of 250-212µm, 212-180µm, 180-125µm and 125-90µm using a sieve stack and shaker. The largest sample size with a sufficient quantity of material was chosen for analysis as there is some evidence for better zeroing (i.e. complete bleaching) of larger grains (Olley *et al.* 1998; Colls *et al.* 2001).

Chemical preparation of the samples was carried out in two stages. Firstly, samples were immersed in 20% hydrochloric acid (HCl) for one hour in order to remove carbonates. Secondly, samples were immersed in hydrogen peroxide (H_2O_2) over night in order to remove organic material.

To separate the quartz and feldspar mineral components from each other, and from any heavy minerals in the sample, density separation was carried out using a centrifuge and sodium polytungstate (SPT or variety Fastfloat LST) heavy liquid. An initial centrifuge run, with the sample placed in sodium polytungstate with a density of 2.70g cm^{-3}, separated quartz and feldspar from heavy mineral contaminants (Mejdahl 1985). A second centrifuge run with the sample placed in sodium polytungstate with a density of 2.58g cm^{-3} separated the quartz and feldspar minerals (Mejdahl 1985).

Quartz samples underwent a further stage of chemical preparation. In order to remove any plagioclase feldspar component remaining in the quartz, samples were immersed in 40% hydrofluoric acid (HF) (Mauz and Lang 2004). This procedure also etches a thin layer from the surface of the quartz grains which may have been penetrated by alpha-radiation while the sediment lay buried. To detect any residual feldspar component remaining in an aliquot, each quartz sample was subjected to an initial test using infra-red stimulation (IRSL), which only produces a response to the feldspar mineral. No feldspar contamination was detected in any sample.

3.3.4 D_e determination

The most common technique currently applied to OSL dating is the single aliquot regenerative dose (SAR) protocol (Murray and Wintle 2000, 2003; Wintle and Murray 2006) which incorporates the application of a fixed test dose to account for sensitivity changes induced during repeated measurement. When applied to a sample, the SAR protocol aims to calculate the amount of laboratory applied radiation that is equivalent to the dose that the sample received while buried (the equivalent dose (D_e), measured in Gy (Gray)). A sample is divided into aliquots (subsamples) of a consistent size, typically 1 or 2 mm, in order to run a series of cycles. Initially, the naturally accumulated dose is measured (Table 3.4) and then this signal is compared to a sequence of applied doses (laboratory regeneration doses). Each aliquot is irradiated at different doses (in this study 1000s, 2000s, 3000s), producing a dose response curve (Figure 3.3a). Within each cycle of the SAR procedure, a fixed test dose is also applied and measured after each laboratory regeneration dose. The test dose result is used to correct the effect of any change in sensitivity that the aliquot undergoes during the repeated SAR cycles. D_e can then be calculated by determining where the natural signal falls on the constructed dose response curve (Figure 3.3b). Due to the use of a fixed beta radiation source (though the dose rate is slowly decaying over time), the SAR protocol is set up in terms of irradiation seconds per aliquot. The original dose rate of the source used in this study was 0.158 Gy/s, producing doses of 158 Gy, 316 Gy and 474 Gy for irradiation times of 1000s, 2000s and 3000s respectively. As the dose rate decays over time a spreadsheet was used to calculate the dose rate of the beta radiation source on the day that a test or SAR protocol was run. The test and SAR protocols were carried out using a RISØ

TL/OSL-DA-20 reader, containing a low-level activity, fully sealed and self-contained beta-emitting ^{90}Sr/Y (Strontium/Yttrium) source.

Table 3.4. The single aliquot regenerative dose (SAR) protocol applied to samples. Preheat temperatures [x°] are determined for each sample during the test procedures prior to the SAR.

	Cycle 1	Cycle 2	Cycle 3	Cycle 4	Cycle 5	Cycle 6
Measuring natural and regenerated luminescence	Dose in nature	Laboratory regeneration dose of 1000s	Laboratory regeneration dose of 2000s	Laboratory regeneration dose of 3000s	Pause 5s	Laboratory regeneration dose of 1000s
	Preheat [x°]	Preheat [x°]	Preheat [x°]	Preheat [x°]	Preheat [x°]	Preheat [x°]
	Measure OSL (L_N)	Measure OSL (L_1)	Measure OSL (L_2)	Measure OSL (L_3)	Measure OSL (L_4)	Measure OSL (L_5)
Measuring luminescence sensitivity	Test dose [499s]	Test dose [499s]	Test dose [499s]	Test dose [499s]	Test dose [499s]	Test dose [499s]
	Preheat [x°]	Preheat [x°]	Preheat [x°]	Preheat [x°]	Preheat [x°]	Preheat [x°]
	Measure OSL (T_N)	Measure OSL (T_1)	Measure OSL (T_2)	Measure OSL (T_3)	Measure OSL (T_4)	Measure OSL (T_5)

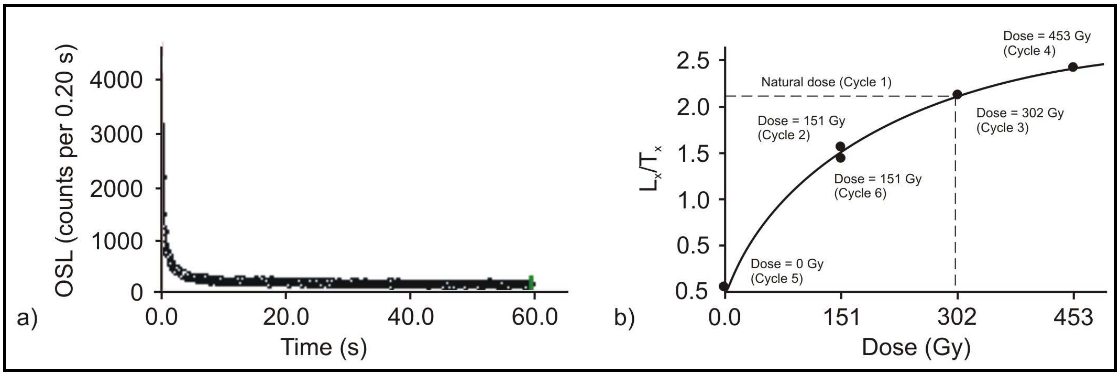


Figure 3.3. a) A luminescence signal produced by a quartz aliquot from sample BRW08 02 and b) The SAR dose response curve from the same aliquot.

3.3.5 Test measurement protocols

Prior to the application of the SAR protocol a number of test sequences were applied to each OSL sample in order to i) determine how well the sample behaved using this protocol and ii) to detect known phenomena that cannot be detected using SAR methods.

The dose recovery test (DRT) (Roberts *et al*. 1999; Wallinga *et al*. 2000; Murray and Wintle 2003) aims to demonstrate that the SAR protocol is able to recover a laboratory induced dose. The DRT introduces a dose of known quantity to a sample after the natural signal has been removed and then treats it as the natural (unknown) signal when a SAR protocol is applied. The resulting measurement should be at or near unity (±10%) with the initial given dose, showing that a given dose can be recovered from a sample by the SAR.

The preheat test (PHT) aims to determine the appropriate preheat temperature to apply to a sample in order to remove the thermally unstable signal components in an artificially induced signal (Aitken 1985). The PHT submits a sample to a range of preheat temperatures and measures the recovered D_e. A preheat plateau should be produced if all the unstable charge is removed, indicating a range of temperatures that produce similar D_e measurements despite the increasing preheat temperature. The preheat temperature to be used in the SAR protocol is then chosen from within this plateau.

The thermal transfer test (TTT) aims to investigate whether electrons are being transferred from thermally unstable to light-sensitive traps (Rhodes and Pownall 1994; Rhodes and Bailey 1997; Rhodes 2000), giving an erroneous D_e during the SAR protocol. The natural signal is first removed from a sample before measurement is then made of the apparent palaeodose, which therefore should be 0 Gy. If a significant signal is recovered by the SAR, showing increasing D_e values with higher preheat temperatures, it would indicate that thermal transfer is occurring and electrons are able to transfer from hard to bleach (i.e. light-insensitive, but heat-sensitive) to easy to bleach (i.e. light-sensitive) traps.

The recycling ratio test aims to detect increased sensitivity in a sample induced by repeated dosing of an aliquot during the SAR procedure, in order to determine if the sensitivity increase is being successfully corrected (as described above). The final irradiation of an aliquot replicates the first (i.e. 1000s), and should produce a signal response ratio between the two doses of unity, within an error margin of ±10% (Murray and Wintle 2000).

The objective of the testing procedure is to find the best performance of each sample, i.e. the most suitable preheat temperature that can be applied in the SAR protocol. Ideally all tests should converge on one preheat temperature.

3.3.6 Age calculation

The equivalent dose, calculated as described above (Chapter 3.3.4), is the total radiation that the sample has absorbed since burial. The equivalent dose used for age calculation was determined from each aliquot that passed the test procedures by means of a central age model (Bailey and Arnold 2006). A further consideration in the calculation of a sediment's age is partial or incomplete bleaching of any residual signal prior to burial, where grains are not exposed to sufficient daylight to fully empty electron traps (Murray *et al*. 1995). Recent approaches to measuring luminescence signals is to assume that sediment grains are both incompletely and differentially bleached prior to deposition (Preusser *et al*. 2008), with some grains holding a residual signal. Lower values in a distribution of palaeodoses will most likely derive from grains that were zeroed, while upper values in the distribution will derive from grains that had residual luminescence at deposition (Murray *et al*. 1995). A Gaussian distribution may identify completely bleached samples but this is not universally the case (Fuchs *et al*. 2007). When a sample shows evidence of partial bleaching any OSL age produced by the mean palaeodose for all aliquots should be considered the maximum age of deposition (Preusser *et al*. 2008).

To calculate the age of a sample the rate at which it has been receiving that energy is required in addition to the equivalent dose. The dose rate is determined using the concentrations of radioactive isotopes of U, Th, and K calculated from the surrounding sediment, in addition to cosmic rays (Chapter 3.3.1). Cosmic radiation is estimated from geographic location of the sample and burial depth (Prescott and Hutton 1994). Moisture content of the sample is also accounted for, as the attenuation of ionising radiation increases if the pores in a sediment are filled with water rather than air (Preusser 2008). The dose rate is corrected for the effects of moisture content following Aitken (1985). Age determination for a sample is made by dividing the palaeodose by the dose rate

$$\text{Age (ka)} = \frac{\text{equivalent dose (Gy)}}{\text{dose rate (Gy ka}^{-1}\text{)}} \qquad (1)$$

The calculations required to produce age determinations for samples were carried out by use of the ADELE (G. Kuhlig, University of Freiberg) software programme.

3.4 Ground Penetrating Radar (GPR)

The aim of the GPR programme was to provide a comprehensive dataset of bedrock elevation and gravel/terrace thickness over key areas that lacked borehole coverage. The programme was designed to investigate the extent and form of terrace features over multiple km transects, reaching a maximum of 6 km in length. Surveys were focused on areas containing sequences of multiple terrace levels (including intervening bluffs) in order to aid stratigraphic differentiation in those areas or at locations where they could contribute to addressing specific research questions. Data collected from GPR surveys were utilised in a number of ways: to aid the construction of long profile projections of terraces and correlation of sequences between different elements of the Solent River and its tributaries; to investigate the extent and frequency of terrace formation; and to address specific research questions. Data from GPR transects were used to generate synthetic borehole logs (see 3.6 below) representative of terrace units.

3.4.1 The GPR method

GPR is an increasingly common non-invasive subsurface geophysical technique which has seen a continuing research and application interest since the mid-1990s (Neal 2004), when some of the fundamental principles of radar propagation in sediments were outlined (Bernabini *et al*. 1995; Dominic *et al*. 1995; Smith and Jol 1995; Tillard and Dubois 1995; Powers 1997; Olhoeft 1998, 2000). The method has been embraced by a number of research fields including civil engineering (Daniels 1996), archaeology (Conyers and Goodman 1997) and geology (Reynolds 1997), with particular attention focusing on sedimentological applications to detect, for example, sedimentary structures/architecture (Corbeanu *et al*. 2001; Best *et al*. 2003; Cardenas and Zlotnik 2003; Skelly *et al*. 2003), boundaries between different sediment types (Dominic *et* al. 1995; van Overmeeren 1998; Vandenberghe and van Overmeeren 1999; Nobes *et al*. 2001; Regli *et al*. 2002) and sediment/bedrock interfaces (Birkhead *et al*. 1996; Arcone *et al*. 1998). This is achieved by sending discrete pulses of high-frequency (MHz) electromagnetic energy into the subsurface, a portion of which is returned upon encountering electrical discontinuities (Figure 3.4). A small point target (such as a tree root, pipe, metal object or large stone) will produce a hyperbola response while planar discontinuities (such as sedimentary changes) will produce reflections (Figure 3.4b). Therefore primary reflections usually parallel primary depositional structures (Neal 2004).

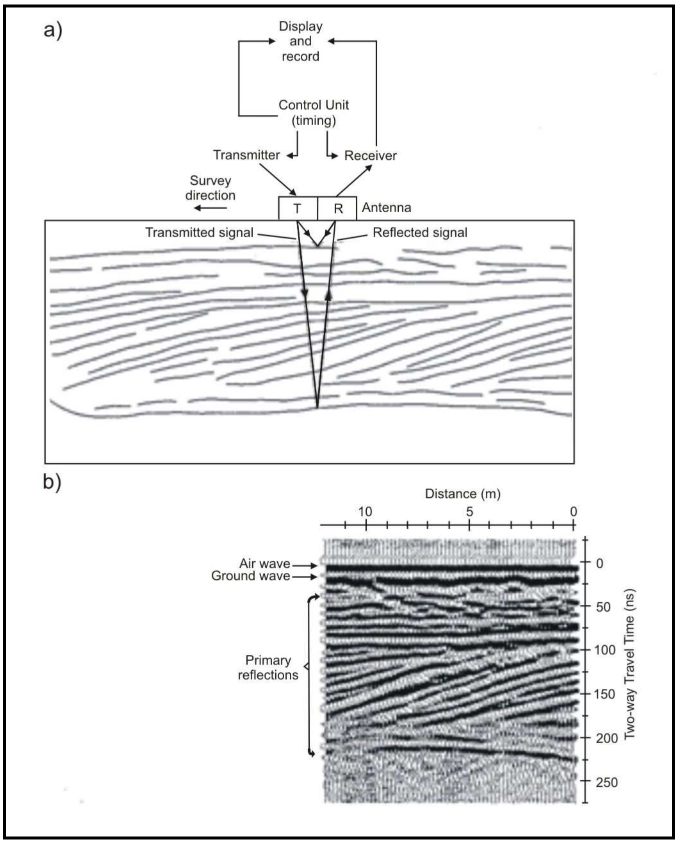


Figure 3.4. The propagation of the GPR signal and the resulting reflection profile. (a) Data acquisition at an individual survey point, showing the GPR system components and subsurface reflector configuration. (b) Radar reflection profile resulting from sequential plotting of individual traces from adjacent survey points (Redrawn from Neal 2004, modified from Neal and Roberts 2000).

Figure 3.4a shows the basic GPR system configuration of transmitting antenna, receiving antenna and (often a single) control unit which initiates the radar signal, displays and records the signal. As the antenna configuration is moved across the ground multiple traces are obtained and stacked to produce a radar reflection profile (Figure 3.4b). Each trace is a measure of the response a sediment or buried object has to the transmitted electromagnetic radar wave based on three fundamental properties: dielectric permittivity (the amount of electrical charge stored and lost when subjected to an alternating electric field), electrical conductivity (the capacity to transport charge when subjected to a static electric field) and magnetic permeability (the amount of magnetic field energy stored and lost when subjected to magnetisation) (Powers 1997; Olhoeft 1998; Walden *et al*. 1999). As the radar wave propagates through the subsurface and encounters sediments and/or objects of different properties the velocity of the signal is affected, and given sufficient response a portion of wave-energy is reflected back to the receiving antenna.

GPR data is collected in time, usually measured in nanoseconds (ns) (10^{-9} s), that a radar signal takes from transmission to reception (the two-way travel (TWT) time). The calculation to then determine the depth of reflections (or discontinuities) in the radar signal is based on TWT and the velocity of the signal, i.e. depth = (velocity x time)/2.

3.4.2 Site selection criteria

GPR surveys were targeted to achieve the longest transects possible, land access allowing, while focusing on sequences of mapped terrace locations. Criteria for the location of GPR survey transects were based upon: regions of the study area that lacked borehole records; the opportunity to survey terrace bluff/transition locations; capturing sequences of successive altitudinally separated terraces; and addressing specific research questions regarding correlation or interpretation of particular terrace landforms, as described in the results chapters.

Various landscapes were surveyed in the region: heath-land, agricultural land and tarmac roads which, while only affecting the near-surface signal, did affect the speed and therefore quantity of data acquisition. Issues of accessibility were also encountered where land was unsuitable for the use of the GPR smartcart-mounted system, usually due to uneven surfaces or the presence of agricultural crops. Where practical, surveys were carried out manually using ‘bi-static’ hand-held frames when the cart could not be used. The specific details for the location of fieldwork sites will be outlined in the results chapters.

3.4.3 Survey methods and data acquisition

GPR surveys were carried out using a Sensors and Software pulseEKKO PRO with 50MHz and 100MHz antenna. The transmitting and receiving antenna are fixed (at 1 m separation) on a wheeled cart which also houses the control unit and battery. Fibre-optic cables link the antenna and control unit. The following settings were used during data capture: The step size of signal traces (i.e. the frequency of readings) was set at 0.5m, with 250 points taken per trace. Antenna separation was at 1m, and the survey mode was reflection. Topographic data was collected by means of differential GPS. Upon initial testing of the equipment it was found that depth penetration obtained with the 100MHz antenna was ~5 m, often insufficient to reach estimated (and observed in the transect conducted) bedrock. The 50MHz antenna was therefore used for each transect carried out, which obtained depths of up to ~20 m.

3.4.4 Calibration of the GPR signal

Once the travel time of the GPR radar-wave from the surface antenna to subsurface reflectors has been determined, the depth of those reflecting interfaces/surfaces can be calculated by establishing the radar-wave velocity (Olhoeft 1981; Vaughn 1986; Imai *et al.* 1987). There are a number of methods for achieving this. On site velocity calculation can be conducted by two methods – reflected-wave or direct-wave. Reflected-wave methods are commonly used during investigation of archaeological sites with features of known depth (e.g. a section of wall) exposed by excavation, when the recorded time taken by the radar-wave to reach the known depth will determine the velocity. This figure will then be applied to the remainder of the site to be surveyed. The nature of the surveys undertaken during this study negates the application of this method. Direct-wave methods such as a common midpoint (CMP) test can be used where excavation is not possible and involve measuring two-way radar travel time from a transmitting to a receiving antenna. By measuring the distance between the two antennas the time taken by the radar-wave to be received can be used to calculate velocity. Direct-wave methods are not as accurate as reflected-wave methods, and a CMP test is only useful for determining near-surface velocities in a few centimetres of subsurface (Tillard and Dubois 1995).

The pulseEKKO PRO software EKKO View Deluxe has the ability to calculate velocity during data processing by measuring the depth and energy propagation of hyperbolic reflections in a GPR section. Due to the nature of the surveys carried out in this study, which investigated undisturbed (except for near-surface road structures etc) terrace deposits, there were no such hyperbola features to utilise. There are also published velocity rates produced by experimentation (Table 3.5; Sensors and

Software 2006). A further method that can be used to check applied velocity rates is by stratigraphic correlation, where reference to nearby stratigraphic sequences may allow the identification of features within a GPR trace.

Table 3.5. Radar velocities through various materials (Sensors and Software 2006).

Material	Velocity (m/ns)	Material	Velocity (m/ns)	Material	Velocity (m/ns)
Air	0.30	Dry Rock	0.12	Silts	0.07
Ice	0.16-0.17	Limestone	0.12	Wet Soil	0.06
Dry Soil	0.15	Wet Rock	0.10	Wet Sand	0.06
Dry Sand	0.15	Concrete	0.08-0.12	Clays	0.06
Granite	0.13	Pavement	0.10	Fresh Water	0.033
Dry Salt	0.13	Shales	0.09	Sea Water	0.033

Initial GPR surveys in the Western Solent region were processed using a figure of 0.11 m/ns for radar velocity as recommended by Sensors and Software (2006) where no other means for calculation are available, checked where possibly against the known stratigraphy of near-by boreholes (Figure 3.5; see Chapter 5). In the Solent Breezes study area (see Chapter 4) the proximity of coastal sections enabled stratigraphic correlation tests to be carried out.

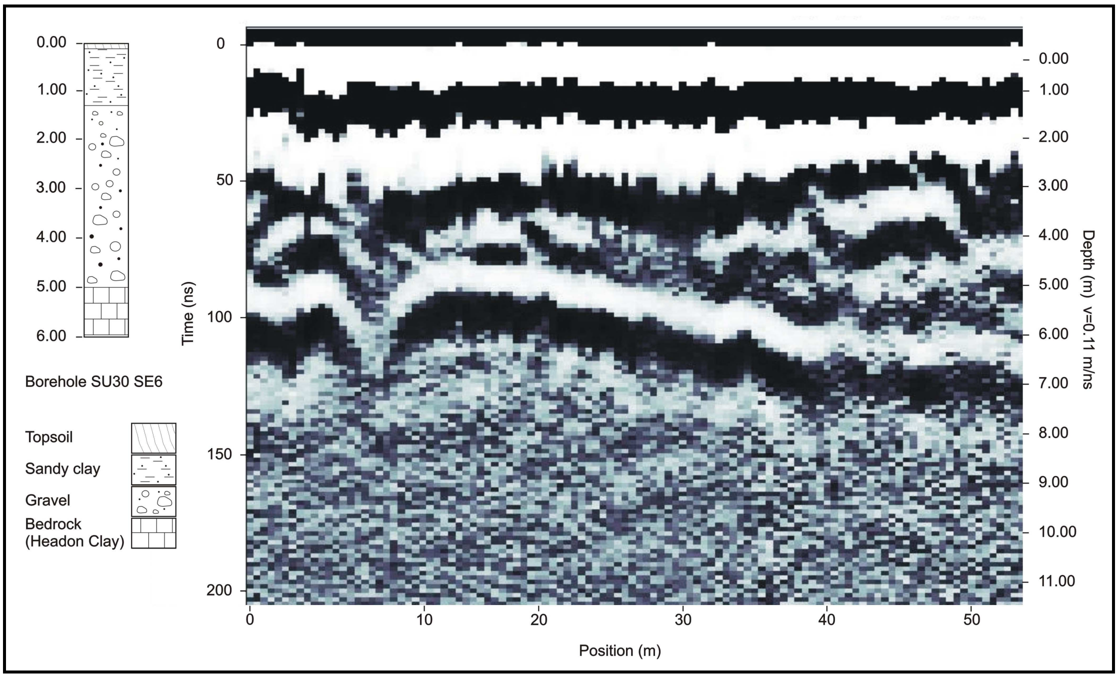


Figure 3.5. GPR trace of transect 3 in the Western Solent with corresponding stratigraphic record. Borehole SU30 SE6 is located ~10 m west of the start (at 0m) of the transect.

At the site of Dunbridge there were no nearby borehole records or sections. As no other calibration method was available a CMP test was conducted in order to obtain an approximation of velocity (Figure 3.6). The furthest recorded separation between the air wave and the ground wave signals occurred after ~137.5 ns with antenna separation at 15 m, producing a velocity of 0.1091 m ns^{-1} using the equation of Robinson and Çoruh (1988):

$$v_1 = \sqrt{[(x_2^2 - x_1^2)/(t_{x2}^2 - t_{x1}^2)]} \qquad (2)$$

where t_{x1} and t_{x2} are the two-way travel times to the ground wave reflection at antenna separations x_1 and x_2 respectively.

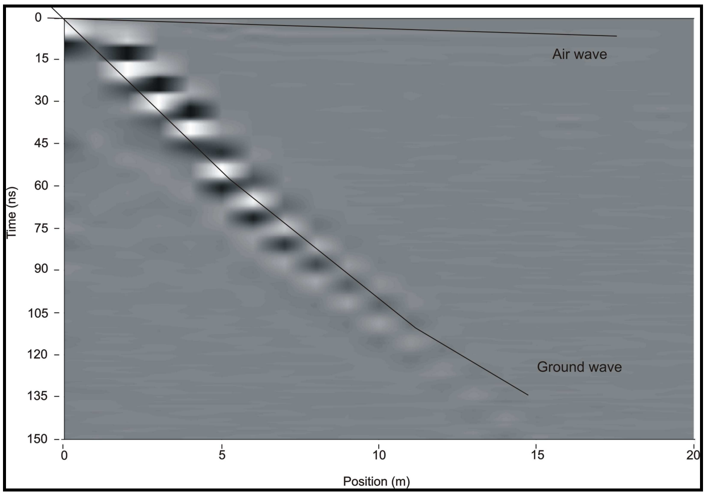


Figure 3.6. The common midpoint (CMP) test conducted at Dunbridge.

3.4.5 Signal processing and interpretation

The raw signal collected by GPR needs some processing to enhance visual presentation and aid interpretation of features. Every GPR signal has to have high-pass temporal filtering known as DEWOW applied. All GPR signal data have a low-frequency component in it referred to as WOW due to receiver saturation induced by the short time interval between the transmitted signal and the large energy input (Fisher *et al*. 1996); if left in a trace/data section the radar signal won’t oscillate around zero but will increase on a lower frequency component which distorts the signal acquired and weakens the detection of discontinuities (Sensors and Software 1999). The application of a high-pass temporal filter (DEWOW) removes the low-frequency component (WOW).

Materials absorb GPR signals so as they move through the subsurface they weaken in strength. Gain applies a function that compensates for the weaker signals with depth.

SEC gain is a spreading and exponential compensation gain that applies a function that most closely replicates the physical reality of the travel of a GPR signal (Sensors and Software 1998). SEC gain applies a function that increases with depth, and retains the relative amplitude between reflectors at different depths in the data produced. Gain functions aid the interpretation of reflections which, for example, may be showing a large contrast between materials above and below a hyperbola or discontinuity (Sensors and Software 1998). An SEC gain function was applied to traces in this study to aid interpretation.

Data collected during the GPR surveys complemented that obtained from the study of borehole records in the region. The aims of the GPR surveys, bedrock surface identification and terrace thickness, was also aided by the stratigraphic information contained in the borehole record. Interpretation of the radar signal traces sought to identify the deepest strong reflector recorded, which from local stratigraphic data was interpreted as the gravel/bedrock interface, the latter typically homogenous clays or sands of several tens of metres depth. The contact identified is often an undulating reflector/reflecting surface where occasional channel or erosional features can be detected (as seen in Figure 3.4).

3.5 Synthetic Boreholes

Synthetic boreholes (SBH) were conceived during this study as a method to easily present the large volume of linear altitudinal data generated during fieldwork. They were used to represent the terrace unit from which they originate in a form that is comparable to borehole records and section logs. In such a format SBH logs could then be included in the generation of long profile projections alongside borehole and section records. SBH logs were generated from Imaging Station and GPR data sets, and consist of ground level, gravel thickness (when discernable) and bedrock surface heights above O.D.

Coastal sections recorded by Imaging Station during the study consist of three-dimensional models produced from data obtained by reflectorless survey of the section face. The surveys produced sufficient detail to determine ground level, gravel thickness and bedrock contact heights along the profile, where vegetation cover or sediment slumping did not obscure contact levels. GPR transects carried out along terrace landforms produced sufficient detail to determine ground level and bedrock contact heights along the profile. The need to use a 50 MHz antenna (in order to obtain sufficient signal depth penetration) meant that the profiles produced were of insufficient detail to determine gravel thickness. The response of the GPR signal to sedimentary change was not strong enough to define either the composition of the gravel beds or the gravel/overburden interface.

Imaging Station profiles were typically of distances from around 20 m to 110 m in length and were located at coastal sections with single fluvial terraces**.** As such, single SBHs were generated to represent the terrace unit. GPR profiles were of distances ranging from around 300 m to 6000 m in length, and in many instances were located in order to record sequences of successive fluvial terraces. GPR profiles which potentially included multiple terraces therefore required further analysis in order to discern the extent of distinct terrace units. Significant breaks of slope (i.e. greater than ~2 m) were initially identified in each ground level and bedrock profile produced. The aim at this early stage was not to determine (or impose) the presence of a distinct terrace surface or define terrace landforms based on examining the individual profile in isolation. The aim was to divide the profile into sections that could then be assessed in terms of their ground level, gravel thickness and bedrock contact heights within the context of the regional stratigraphic sequence. Areas of transition, which could be the degraded/down-cut bluff of the higher, older terrace, were removed so as to not skew the data for the intervening terrace/bedrock topography. Modern valley features were also removed from the data set so that the reduced ground surface and bedrock heights in the profile did not bias the terrace topography data.

Trend lines were produced for ground level, gravel thickness (where discernable) and bedrock surface heights for each potential terrace. Polynomial and linear regressions of gravel thickness and bedrock profiles were calculated in Excel spreadsheets (Figure 3.7). Mean values of altitudinal data were also produced for comparison, and this data usually closely matched the linear trend line. Figure 3.7 shows that where a bedrock profile is particularly uneven (e.g. trend line 5) a polynomial regression may produce a trend line that varies considerably. The format chosen to produce each SBH was therefore to calculate bedrock height and gravel thickness from the mean or linear trend line data of the profile section and the actual ground level height at the location of the mean (Table 3.6). These values were then used to create SBHs for each potential terrace level, for use in the production of long profile projections. Only at this stage, when (SBH) profile data were assessed alongside a complete regional dataset, were terrace attributions confirmed.

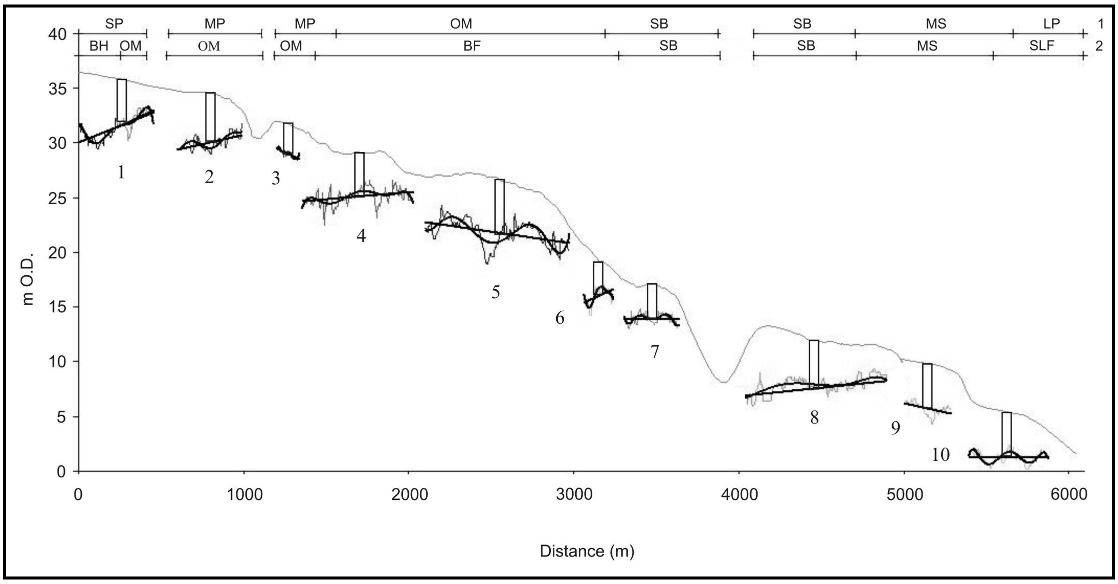


Figure 3.7. An example of polynomial and linear regression trend lines on GPR profile 3 from the Western Solent region. The locations of synthetic boreholes are marked by columns. Terrace nomenclature: SP Setley Plain; BH Beaulieu Heath; MP Mount Pleasant; OM Old Milton; BF Becton Farm; SB Stanswood Bay; MS Milford on Sea; LP Lepe; SLF St Leonards Farm. Stratigraphic model 1: Allen and Gibbard 1993; 2: Westaway *et al*. 2006.

Table 3.6. Synthetic borehole data generated from GPR transect 3 in the Western Solent region 2. The current terrace attributions of Allen and Gibbard (1996) and Westaway *et al*. (2006) are shown.

Reference	Easting	Northing	Ground level (m O.D.)	Terrace thickness (m)	Bedrock height (m O.D.)	Terrace Allen & Gibbard	Terrace Westaway *et al*
WSOL23 1	437407	100519	35.75	4.32	31.43	Setley Plain	Old Milton
WSOL23 2	437137	100036	34.41	4.32	30.09	Mount Pleasant	Old Milton
WSOL23 3	436864	099669	31.69	2.69	29.00	Mount Pleasant	Old Milton
WSOL23 4	436834	099257	29.10	4.02	25.08	Old Milton	Becton Farm
WSOL23 5	436817	098412	26.76	4.99	21.77	Old Milton	Becton Farm
WSOL23 6	436845	097805	19.46	3.42	16.04	Stanswood Bay	Stanswood Bay
WSOL23 7	436809	097529	17.00	3.10	13.90	Stanswood Bay	Stanswood Bay
WSOL23 8	436120	096639	11.61	3.91	7.70	Stanswood Bay	Stanswood Bay
WSOL23 9	436298	096004	9.10	3.38	5.72	Milford on Sea	Milford on Sea
WSOL23 10	436391	095560	5.50	4.25	1.25	Lepe	St Leonards Farm

3.6 Construction of revised mapping, long profile projections and terrace gradients

3.6.1 Geographic Information System

The primary tool for handling data produced during the study was the Geographic Information System (GIS) software ArcGIS 9.2. The programme enabled all mapping for the study, which was based on BGS digital geological map tiles of the study area (BGS 2009a-h). In addition Ordnance Survey 1:10 000 scale map tiles were entered into the GIS to provide geographical detail and to aid fieldwork location planning.

ArcCatalog was used to manage geographic/spatial datasets and database designs, and for recording, viewing and managing metadata. Data were imported via the use of Microsoft Access databases. ArcMap was used for mapping and editing tasks in addition to map-based analysis. Databases of geographic information were generated from the various sources collated by this study: fieldwork carried out by the study (section logs, OSL sampling and GPR survey locations and SBHs), the available BGS borehole records and published data produced by other studies in the Solent River system region. These datasets are defined in the relevant results chapters (Chapters 4, 5 and 6).

3.6.2 Long profile projections and terrace mapping

The generation of terrace reconstructions was achieved by means of a multi-stage method of long profile projection and terrace mapping analysis, in order to assess and revise current stratigraphic schemes of the Solent River system. Revised long profile projections were produced for the terrace stratigraphies of each region of the study area, the Test Valley, the Western Solent and the Bournemouth regions, with the latter divided into Solent and Stour deposits. Sub-regional long profiles or cross-sections were also produced where necessary to aid analysis (see Chapters 4, 5 and 6).

Sedimentary data were imported as vertical logs into RockWorks 15 software, a subsurface-data visualisation tool able to generate long profile projections on a user-defined projection plane. Projection planes were selected based on the geometry of terrace bodies, either as the entire sequence (reflecting a generalised orientation of a region’s terraces but able to incorporate a complete scheme), as individual terrace levels (to more accurately reflect the specific orientation of each terrace level, see section 3.6.3 below) or as cross-sections, as required for analysis. The RockWorks multi-log profile tool then determined the location of each log along the profile by perpendicular projection onto the chosen projection plane. Altitudinal data of bedrock contact and gravel thickness were used to produce envelopes of terrace deposits for correlation, drawn from the RockWorks long profile outputs.

The initial long profile projections, produced using the expanded dataset generated by this study, were then used in conjunction with GIS mapping of terrace distributions to assess each current interpretation of the various regional stratigraphies. Assessment of the robustness of each long profile projection was made based on its internal consistency in relation to altitudinal gradient change downstream or across a section. Concurrent with examining altitudinal consistency, each log was assessed in relation to its location within a mapped terrace unit using ArcGIS outputs. Factors that were considered when making a determination on the accuracy of a log‘s altitude or terrace attribution were: proximity to the mapped edge of an altitudinally higher or lower terrace level; proximity to the front edge of its assigned terrace level (possibly eroding or indicative of solifluction); topographic landscape features potentially causing post-depositional alteration (e.g. tributary river or stream valley-side erosion, gullying); location towards the back edge of a terrace (often thicker) or the front edge (often thinning); potential for localised variation in bedrock topography (e.g. scour or channel features); and human error in data recording (e.g. location or stratigraphic data entry errors). Assessments were made by examining logs both individually and within the context of other nearby records, often by generating sub-regional long profiles or cross-sections. After the dataset had been analysed, with terrace attributions maintained or reassigned, new long profiles were produced in order to assess the validity of any proposed revisions. Such reassignments that were deemed the most parsimonious solution to the location of a particular log could result in revisions to its attribution to a terrace level and/or the mapped extent of a terrace unit, or the removal of the log from the dataset.

3.6.3 Terrace gradients

Terrace gradients were constructed for each individual terrace level in the Test Valley, the Western Solent and the Bournemouth regions as revised by the methods set out in section 3.6.2. Location data for each borehole, fieldwork section log or SBH was initially entered into a SigmaPlot 11.0 spreadsheet. A linear regression trend line was produced of the location data for records in each terrace, which produced a projection plane based on the geographic distribution of that data (Figure 3.8; Table 3.7). Terraces that were problematic are noted in the appropriate results chapter below. Each data point was then manually projected perpendicularly onto the trend line in order to determine the distance of that data point along the plane of projection. The bedrock height and distance along the plane of projection data for each record/log was then entered into a further SigmaPlot 11.0 spreadsheet in order to produce a linear regression trend line of the terrace gradient. The downstream gradient of bedrock elevation for each terrace could then be calculated from the start and end points of the gradient trend line, expressed as x m km^{-1}. The gradients produced are discussed in Chapter 8.

The methods outlined above produced a substantial resource for examining the stratigraphy of the Test Valley, Western Solent and Bournemouth regions. The data set necessitates the use of geomorphological approaches to the subdivision of the terrace stratigraphy of the Solent River system, underpinned by chronological tie-points. The results from fieldwork and data analysis are provided in Chapters 4, 5 and 6 respectively, and geochronology is discussed in Chapter 7.

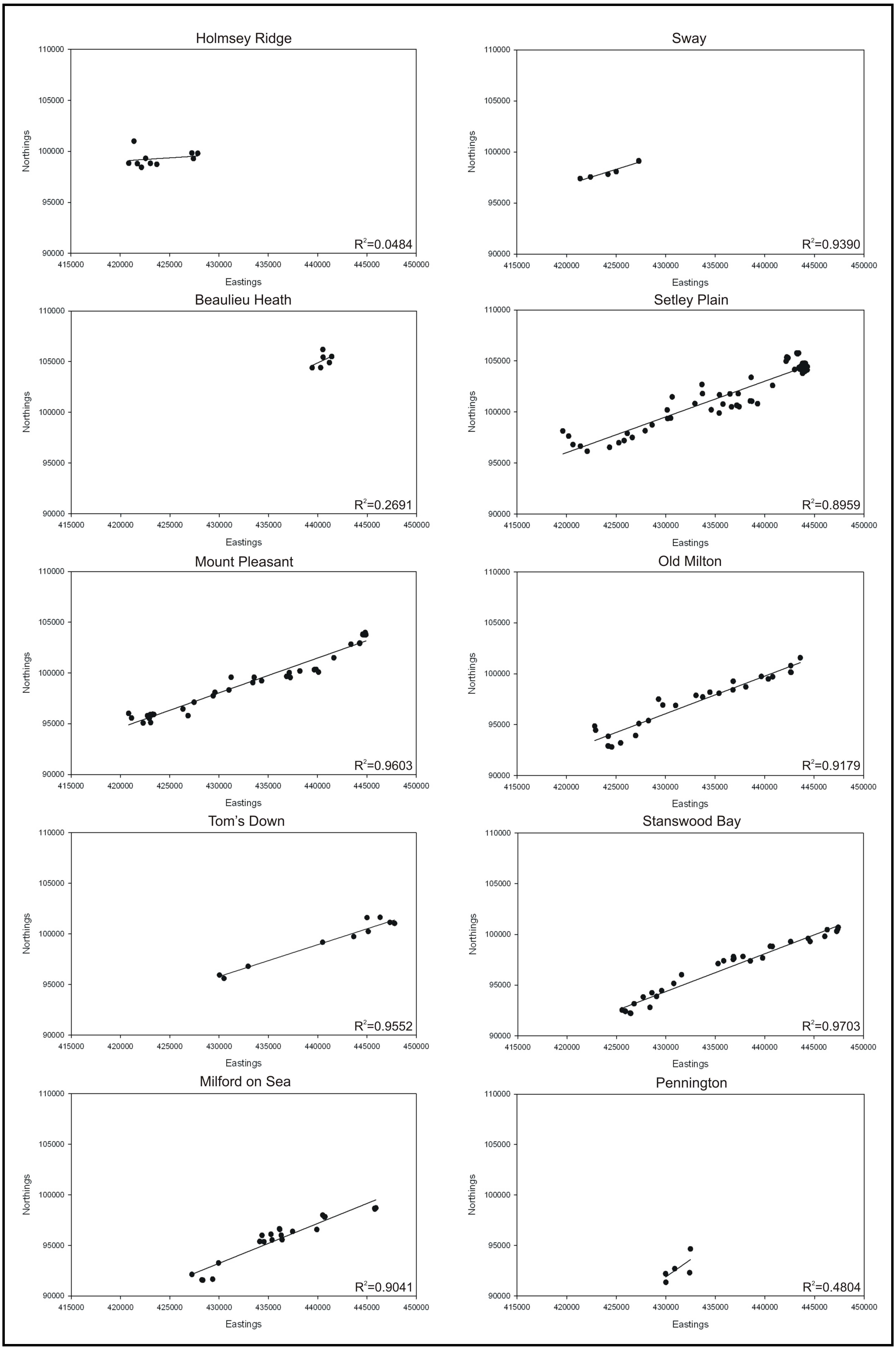


Figure 3.8. Data used in the production of projection planes for terraces in the Western Solent region, which provided the orientation for terrace gradients used to correlate upstream into the Bournemouth region and downstream into the River Test region. Linear regression equation: f = y0+a*x.

Table 3.7. Associated statistics for the linear regression (f = y0+a*x) data shown in Figure 3.8 above.

Terrace	R^2	Variable	Coefficient	Std. Error	t	P
Holmsey Ridge	0.0484	y0	72833.7892	41464.6554	1.7565	0.1171
		a	0.0624	0.0978	0.6380	0.5413
Sway	0.9390	y0	-30041.8307	16346.0313	-1.8379	0.1399
		a	0.3020	0.0385	7.8444	0.0014
Beaulieu Heath	0.2691	y0	-93636.1838	133814.7736	-0.6997	0.5103
		a	0.4512	0.3036	1.4861	0.1878
Setley Plain	0.8959	y0	-50852.7452	5265.9151	-9.6570	<0.0001
		a	0.3497	0.0120	29.1936	<0.0001
Mount Pleasant	0.9603	y0	-49649.6072	4786.3557	-10.3732	<0.0001
		a	0.3435	0.0110	31.1111	<0.0001
Old Milton	0.7994	y0	27.7596	0.6068	45.7465	<0.0001
		a	-0.0005	0.0000	-9.5732	<0.0001
Tom's Down	0.9552	y0	-39314.2985	9511.2362	-4.1335	0.0020
		a	0.3142	0.0215	14.6043	<0.0001
Stanswood Bay	0.9703	y0	-65729.4730	4877.0117	-13.4774	<0.0001
		a	0.3723	0.0112	33.3020	<0.0001
Milford on Sea	0.9041	y0	-76374.0284	12229.9287	-6.2448	<0.0001
		a	0.3944	0.0280	14.0723	<0.0001
Pennington	0.4804	y0	-204786.1895	154666.3594	-1.3241	0.2561
		a	0.6899	0.3588	1.9231	0.1268

CHAPTER FOUR: THE TEST VALLEY

4.1 Introduction

Remnant fluvial gravels of the Pleistocene River Test survive alongside the modern course of the river, recognisable from north of the confluence with the River Dun downstream to Southampton Water (Figure 4.1). From here Test deposits are predominantly found on the eastern bank of Southampton Water, with patches of only the lowest two terraces remaining on the west bank. Eleven River Test terraces are recognised in the BGS Southampton Sheet (Sheet 315) in the mapping scheme of Edwards and Freshney (1987), while the BGS Winchester Sheet (Sheet 299) has eight River Test terrace levels (Booth 2002). The two sheets are mapped independently with different numbering schemes which makes terrace correlation difficult, particularly with the Dunbridge area (Chapter 4.2 below). There is initial agreement in the two schemes as Terraces 1 and 4 persist across both sheets, while Terraces 2 and 3 cease north of Romsey and do not appear in the south of sheet 299. At Dunbridge however Booth (2002) recognises two intermediate terrace levels without differentiating between them, attributing them to Terrace 2/3. The correlation between the two BGS sheets is therefore significant for the terrace stratigraphy of the River Test as a whole. The schemes of the PASHCC project (Bates *et al*. 2004; Briant *et al*. 2012) and Westaway *et al*. (2006; cf. Harding *et al*. 2012) differ in the projection of long profiles of terrace fragments between Sheets 299 and 315, while the latter scheme also reassigns some downstream terrace deposits in Sheet 315 in the process (see Chapter 2.4). These issues are outlined in sections 4.2, 4.3 and 4.4 below.

During the current investigation fieldwork was undertaken at Dunbridge, Warsash, Chilling Copse and Solent Breezes, while unpublished sedimentary data and OSL samples were made available from previous work at Brownwich Lane (Figure 4.1). Sites for investigation were selected primarily with the aim of providing additional data through excavation, coastal section recording and GPR in order to address the specific research aims set out below. Data generated by section recording and GPR is summarised by the generation of synthetic boreholes as described in Chapter 3.5 (Methods) to enable it to be incorporated within a database of sub-surface information. The results of these investigations are presented in sections below (4.2

Dunbridge, 4.3 Warsash, and 4.4 Chilling Copse and Solent Breezes), along with an examination of the available borehole archive in the region (4.5).

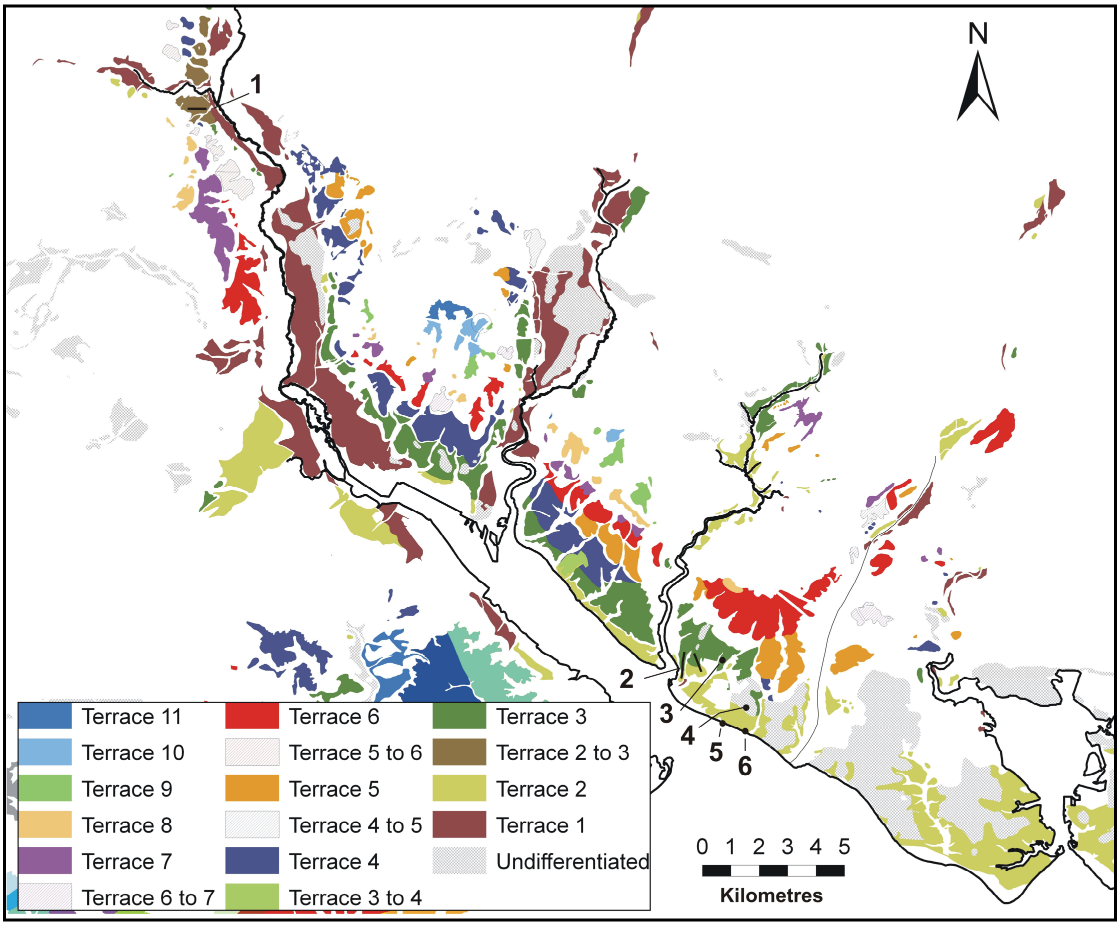


Figure 4.1. Location map of fieldwork sites and terrace attributions (Edwards and Freshney 1987; Booth 2002) in the Test Valley region. Fieldwork sites are numbered: 1. Dunbridge (GPR). 2. Newtown Road and Church Road, Warsash (GPR). 3. Hamble Park and Warsash Common quarries, Warsash (excavation of quarry sections and OSL). 4. Chilling Copse (GPR). 5. Solent Breezes (coastal section recording). 6. Brownwich Lane (coastal section recording and OSL).

A number of specific research aims were identified for the Test Valley region. These were: A) to establish the relationship between the terraces at Dunbridge and those downstream at Warsash; B) to determine how the lower Test terraces (as seen at Warsash and Solent Breezes) relate to those in the Western Solent region (Chapter 5); C) to establish the age of the archaeologically important River Test Terrace 3 and D) to utilise all the available data to produce a revised stratigraphic model of the fluvial terraces of the Test Valley region..

In order to attempt to address these research aims a number of methods were utilised in a multi-technique approach. Laterally extensive coastal sections were recorded at

Solent Breezes using a Topcon Imaging Station (Chapter 3.2.3) and vertical sedimentary logs were also recorded where sections were accessible. *In situ* terrace deposits were recorded by excavation of former quarry sections at Hamble Park and Warsash Common quarries (Chapter 3.2.2). These data contribute to better defining the River Test terrace stratigraphy and how it relates to the Western Solent sequence (aims A and B). Samples were taken from sand lenses within quarry sections for OSL dating where they were deemed suitable, in order to obtain ages for Terrace 3 at Warsash (aims B and C). GPR surveys were conducted at either end of the main Test sequence at Dunbridge, Warsash and Chilling Copse. Data produced by GPR investigation contribute to the correlation of terraces at either end of the sequence, a clearer understanding of the River Test terrace stratigraphy and how the Test terraces relate to the Western Solent sequence (aims A and B). The available borehole archive from the Test Valley region was examined alongside data produced during fieldwork. This dataset was used to construct long profile projections of the River Test terraces which contribute to better defining the Test stratigraphic sequence and how it correlates with the Western Solent sequence (aims A and B). Finally, all of the analyses carried out in the Test Valley Region contributed to the production of a revised stratigraphic model of the fluvial terraces of the River Test (Aim D). The comparison between the Test valley long profile projection and that produced by terrace deposits in the Western Solent region are used (alongside OSL ages of the Warsash deposits) to attempt correlation between the main Solent sequence and that of the tributary Test. Fieldwork and data analyses were carried out as described in Chapter 3 (Methods).

4.2 Dunbridge

Dunbridge is located at the confluence of the River Dun and River Test (Figure 4.2) and the site lies on Pleistocene fluvial deposits of the Test. Bedrock in the area consists largely of Palaeocene Reading Beds with some Eocene London Clay in the immediate vicinity of Dunbridge, with Late Cretaceous Chalk to the north. BGS mapping of the fluvial terraces in the area (Booth 2002) recognises the presence of two levels at Dunbridge but does not differentiate between them. They are identified as an undifferentiated Terrace 2/3, with further areas of Terrace 1 to the east of Dunbridge. To the south and south east there are spreads of each of the eight mapped terraces on the Winchester sheet (BGS Sheet 299), although they do not survive consistently and many gaps exist in the sequence. Fragmentary remnants of these terrace levels are recognised on the Winchester sheet upstream and downstream from the Dunbridge area.

The need to better define the terrace attribution in the area and identify how those terraces correlate with those downstream in the Southampton sheet requires a re-investigation of the terrace stratigraphy. However, in the Dunbridge area a lack of suitable locations to examine *in situ* deposits via excavation restricted investigations to a GPR survey and an examination of the available borehole archive. In addition the results of a long-term geoarchaeological watching brief conducted at Dunbridge (Harding *et al*. 2012) have been included within the database for the Test Valley.

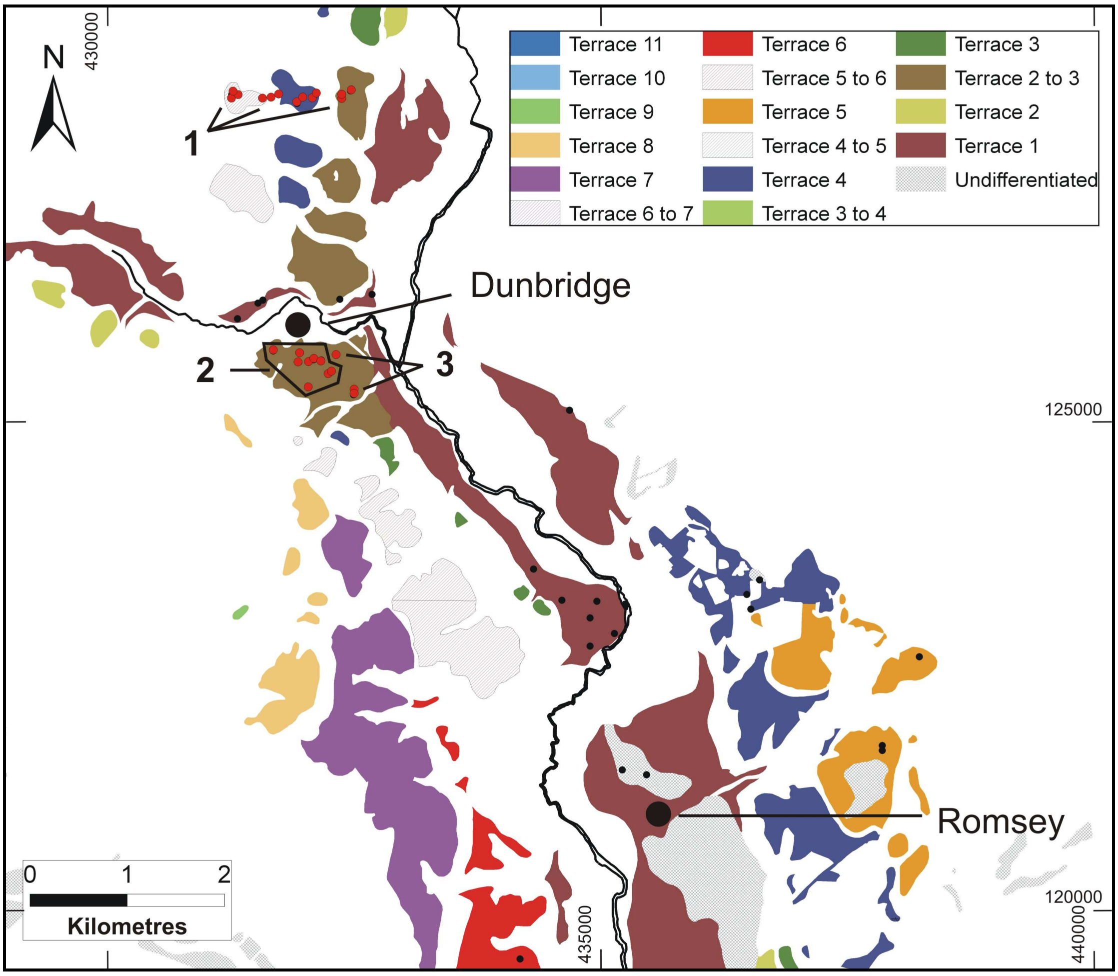


Figure 4.2. Location map of fieldwork sites and terrace attributions (Booth 2002) in the Dunbridge area. Fieldwork sites in red: 1. PASHCC test pits. 2. Harding *et al*. 2012 borehole locations. 3. GPR surveys carried out for this study. Black circles indicate boreholes used in long profile projections below.

4.2.1 Previous work: Dunbridge

The archaeological importance of the Dunbridge/Kimbridge area was first indicated by the discovery of Palaeolithic artefacts in two quarry locations (Dale 1912, 1918). White (1912) recognised two altitudinally distinct terrace levels, a higher ‘Belbin Stage’ terrace at the Dunbridge quarry and lower ‘Mottisfont Stage’ terrace in a nearby Kimbridge quarry. Recent re-investigation of the terrace stratigraphy in the Dunbridge area (Bridgland and Harding 1987; 1993; Harding *et al*. 2012; Bates *et al*. 2004, 2007; Bates and Briant 2009; Briant *et al*. 2012) has produced different correlations of the Dunbridge terraces with the long profile projections of the Test as a whole (Table 4.1). Bridgland and Harding (1987; Harding *et al*. 2012) correlate Booth’s (2002) Terrace 2/3 at Dunbridge with Terraces 3 and 4 in the Edwards and Freshney (1987) scheme to the south, naming them the Mottisfont and Belbin terraces respectively. This interpretation is based on data obtained during a geoarchaeological watching brief carried out at Kimbridge Farm quarry (SU 321 255) between 1991 and 2007. Terrace deposit modelling (Harding *et al*. 2012) (Table 4.2; Figure 4.3) defines the Belbin terrace with an average altitude of between 44.8 ±1.9 m O.D. and 42.0 ± 1.9 m O.D. from surface to bedrock contact. The Mottisfont terrace ranges with an average altitude between 38.2 ±2.3 m O.D. and 35.7 ± 2.9 m O.D. from surface to bedrock contact. In contrast, the PASHCC scheme (Bates *et al*. 2004, 2007; Bates and Briant 2009; Briant *et al*. 2012) correlates Booth’s (2002) Terraces 2/3 at Dunbridge with Edwards and Freshney’s (1987) Terraces 4 and 5. Around one mile to the northeast of Dunbridge, Test pitting within Booth’s (2002) Terrace 2/3 around Mottisfont (SU 324 284) (Table 4.3) records the terrace surface between 49 and 44 m O.D., with bedrock contact between around 46.3 m O.D. and 41.8 m O.D.

Table 4.1 Terrace correlations between BGS sheets 299 (Winchester) and 315 (Southampton) as proposed by Harding *et al*. (2012) and the PASHCC project (Bates *et al*. 2004; Briant *et al*. 2012).

Terrace	BGS Winchester sheet (Booth 2002)	Downstream River Test terrace correlation: Harding *et al*. 2012	Downstream River Test terrace correlation: PASHCC
Belbin/Upper Warsash	Terrace 2/3	Terrace 4	Terrace 5
Mottisfont/Lower Warsash		Terrace 3	Terrace 4

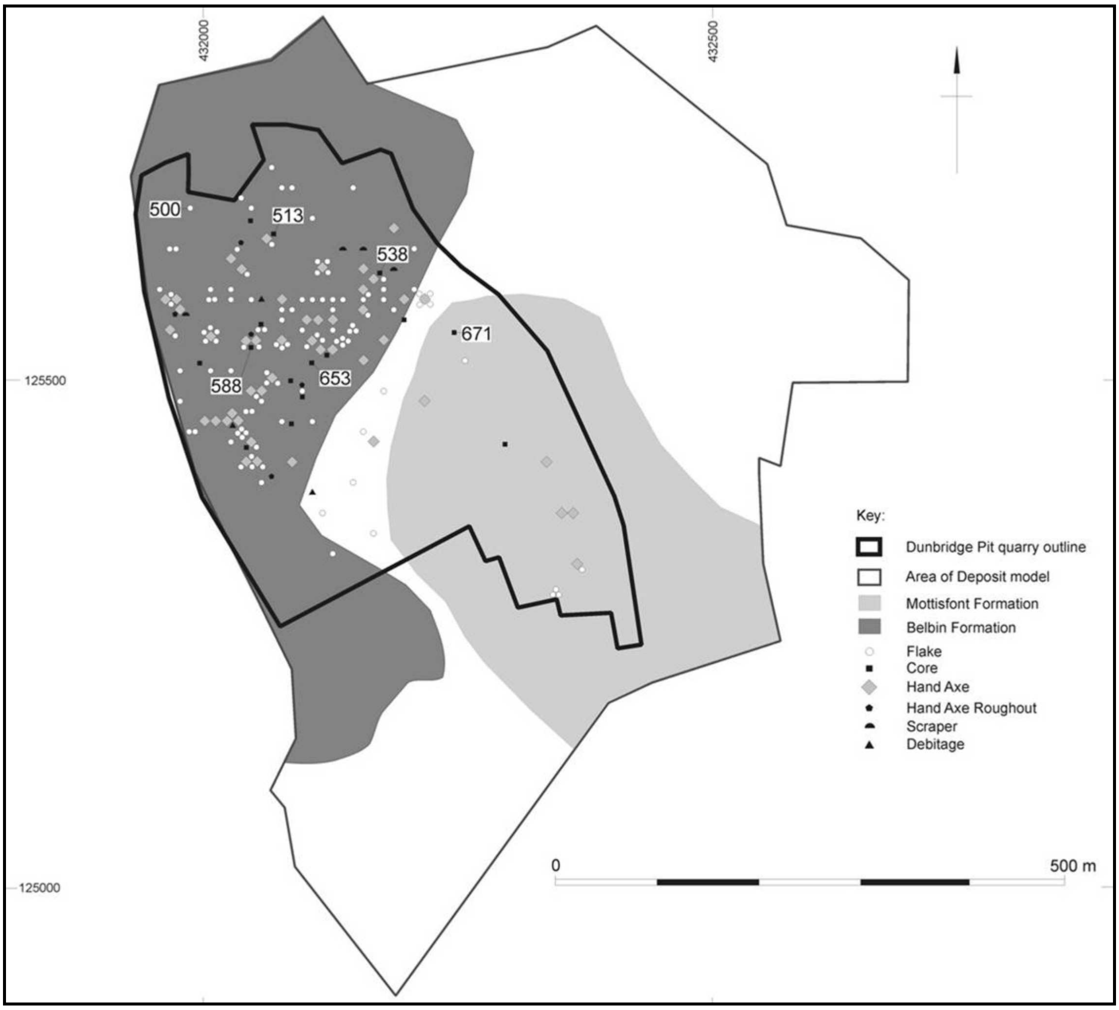


Figure 4.3. Belbin and Mottisfont terrace footprints in the Dunbridge area produced by the digital terrain model of Harding *et al.* (2012).

Table 4.2 Section data recorded at Dunbridge by Harding *et al*. (2012), located in BGS Terrace 2/3 (Booth 2002), with their proposed correlation with the main River Test sequence.

Reference	Easting	Northing	Ground level (m O.D.)	Gravel thickness (m)	Bedrock height (m O.D.)	Terrace Westaway *et al*. 2006	Correlation with BGS Terrace
DUN S1	431930	125625	47.80	4.20	43.50	Belbin	Terrace 4
DUN S2	432030	125630	45.70	2.60	42.80	Belbin	Terrace 4
DUN S3	432080	125650	45.10	3.20	41.90	Belbin	Terrace 4
DUN S4a	432155	125640	44.40	6.40	37.90	Belbin	Terrace 4
DUN S4b	432160	125645	44.40	3.15	41.15	Belbin	Terrace 4
DUN S13	432025	125370	46.80	-	No contact	Belbin	Terrace 4
DUN S14	432255	125520	41.80	1.90	38.90	Mottisfont	Terrace 3
DUN S15	432260	125525	42.00	-	No contact	Mottisfont	Terrace 3
DUN S16	432230	125505	41.50	2.50	39.00	Mottisfont	Terrace 3

Table 4.3 Test pit data recorded around Dunbridge by the PASHCC project (Bates *et al*. 2004) with their proposed correlation with the main River Test sequence.

Reference	Easting	Northing	Ground level (m O.D.)	Gravel thickness (m)	Bedrock height (m O.D.)	BGS Terrace (Winchester sheet)	Correlation with BGS Terrace
SPW03 TP1	431300	128370	74.45	1.00	73.20	Terrace 5/6	Terrace 8
SPW03 TP2	431240	128370	74.90	1.35	73.30	Terrace 5/6	Terrace 8
SPW03 TP3	431270	128380	74.60	0.80	73.60	Terrace 5/6	Terrace 8
SPW03 TP4	431240	128330	77.00	1.05	75.55	Terrace 5/6	Terrace 8
YTC03 TP4	431560	128330	68.50	2.80	65.40	Terrace 5/6	Terrace 8
YTC03 TP1	431720	128370	64.30	2.20	61.45	Terrace 4	Terrace 7
GTC03 TP1	432100	128380	57.10	1.20	55.60	Terrace 4	Terrace 7
GTC03 TP2	431910	128280	60.00	1.90	57.80	Terrace 4	Terrace 7
GTC03 TP3	432070	128340	58.75	2.25	56.10	Terrace 4	Terrace 7
GTC03 TP4	431970	128340	59.30	1.45	57.60	Terrace 4	Terrace 7
MTF03 TP1	432460	128410	44.73	2.15	42.18	Terrace 2/3	Terrace 5
MTF03 TP3	432370	128340	48.50	1.45	46.60	Terrace 2/3	Terrace 5

4.2.2 Ground Penetrating Radar: Dunbridge

The GPR survey carried out at Dunbridge (Figure 4.4) was conducted using techniques described in Chapter 3.4, using both the wheeled cart and bi-static frames. The terrain in three of the four fields surveyed at Dunbridge was pasture land, sometimes holding livestock. As a result the ground surface was too uneven for the pulseEKKO PRO smartcart to negotiate and these surveys were conducted using the hand-held frames to move the GPR antenna along transects. For the majority of transects conducted by hand (Lines A, B, C and E) two-metre steps were used. This was necessary in order to complete the survey in the time available. The increased antenna separation resulted in a slightly lower resolution data output to the GPR line traces, with the exception of Line D which was carried out first with one-metre steps. Topographic data of each transect was collected by differential GPS. Data provided by the GPR survey was used to produce SBH logs (Table 4.4 below). This data is used in the construction of long profile projections of the Test terraces in section 4.5 below. The GPR survey at Dunbridge was carried out before publication of Harding *et al*.'s (2012) terrace deposit modelling in the area.

Line A (SU 3230 2570) (Figure 4.5) was 193.50 m in length, with ground level along the transect starting at 44.49 m O.D. at the west end. Ground level drops to 37.67 m O.D. at the east of the transect as the terrace slopes towards the modern River Test. The resolution of the GPR signal was somewhat affected by low battery power as the line was the last to be carried out during the survey, but not significantly. Strong planar reflections in the returned GPR signal are detected throughout the profile, indicating significant sedimentary discontinuities. The deepest strong reflector is seen to vary between 2.0 m to 4.5 m in depth (c.41.0 to 35.5 m O.D.). Below this reflection the largely non-responsive signal is indicative of a substantial unit with little sedimentary change, likely to be the fine-medium sands of the Reading Formation bedrock in the area. DUN SBH1 records ground level at 42.1 m with bedrock contact at 38.46 m O.D.

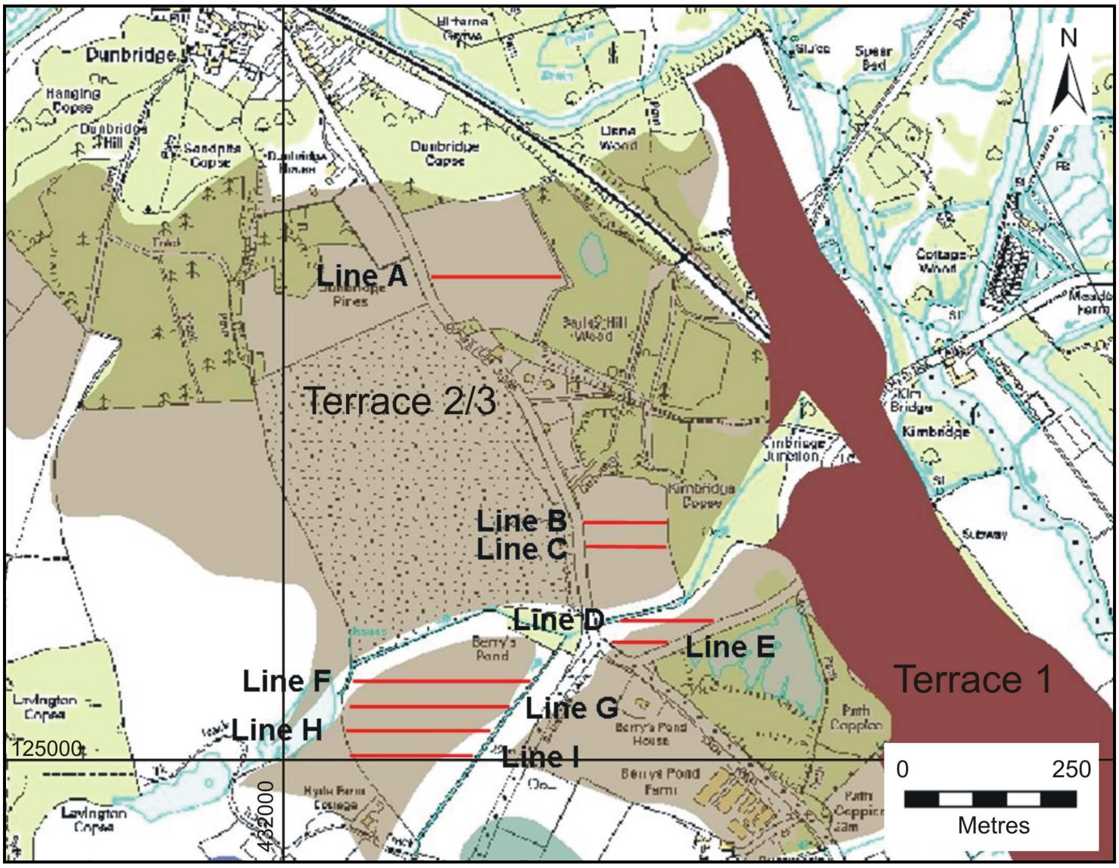


Figure 4.4. Location map of GPR transects carried out in the Dunbridge area.

Line B (SU 3249 2533) (Figure 4.6) was 124.00 m in length, with ground level along the transect starting at 36.13 m O.D. at the west end. Ground level drops to 33.53 m O.D. at the east of the transect as the terrace slopes towards the modern River Test. The deepest reflector can be seen at depths of between 3.3 to 4.5 m (c. 32 m to 30 m O.D.). DUN SBH2 records ground level at 34.97 m with bedrock contact at 30.76 m O.D. Line C (SU 3249 2528) (Figure 4.7) was 130 m in length, with ground level along the transect between 36.61 m O.D. at the west to 32.74 m O.D. The deepest strong reflector can be seen at depths of between 2.5 to 5.5 m (around 33 m and 29 m O.D.). This signal corresponds with the signal in Line B, 40 m to the north. DUN SBH3 records ground level at 35.74 m with bedrock contact at 31.42 m O.D.

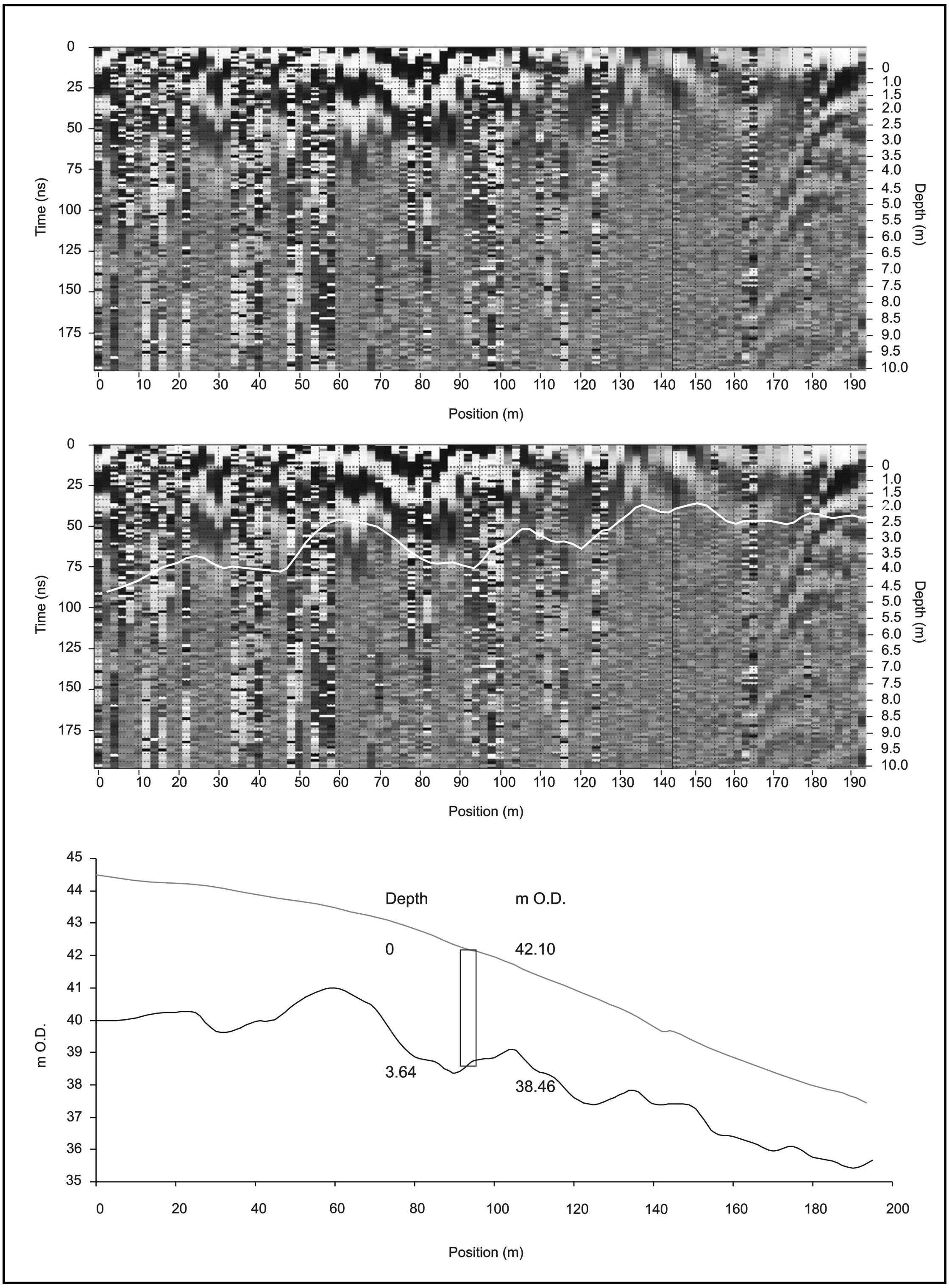


Figure 4.5. West to east GPR trace output of Line A at Dunbridge (SU 3230 2570) (top) with interpretation of bedrock contact (middle). Transect at 2 m steps. Bottom image is a profile of GPR Line A at Dunbridge with synthetic borehole DUN SBH 1 location and heights shown.

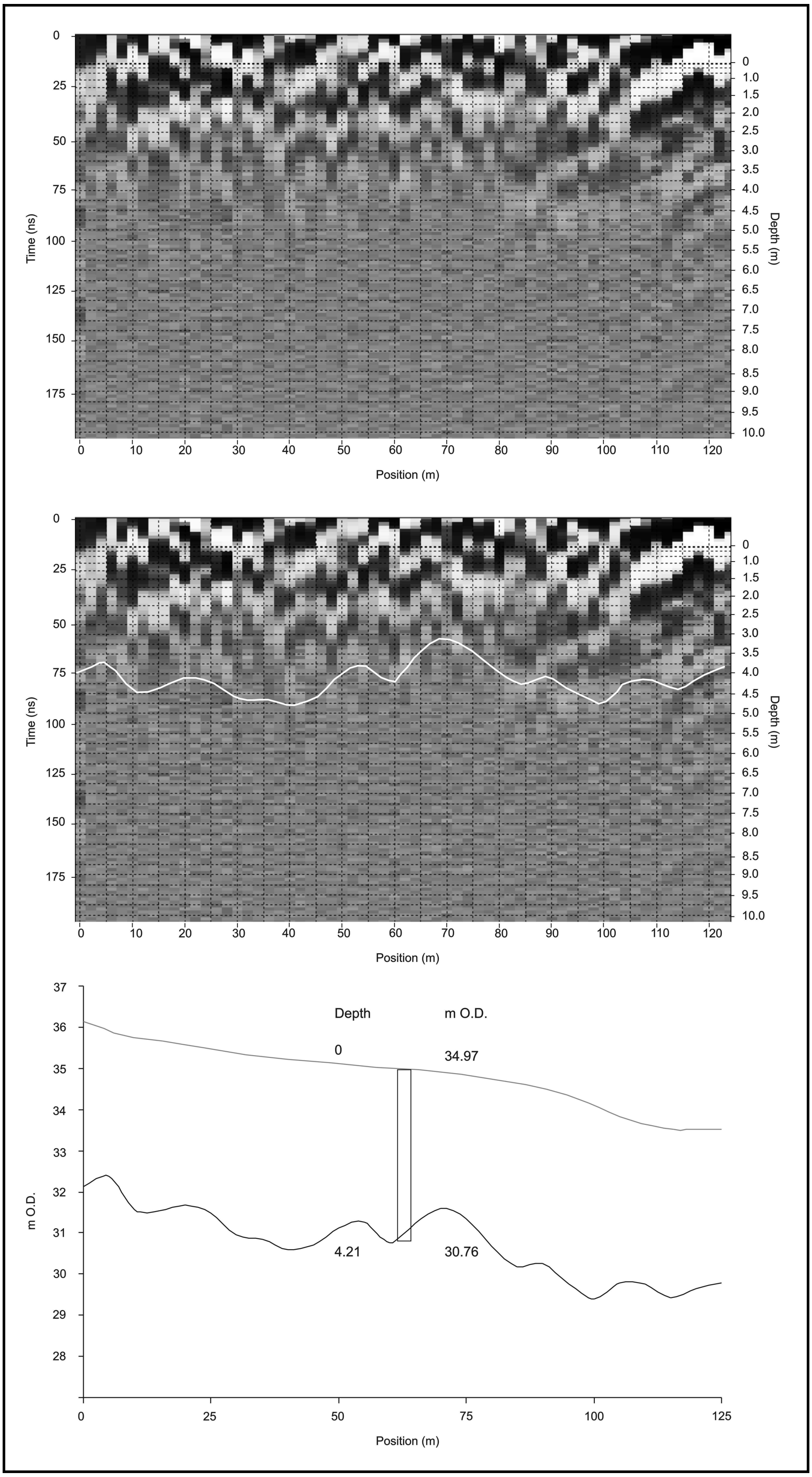


Figure 4.6. West to east GPR trace output of Line B at Dunbridge (SU 3249 2533) (top) with interpretation of bedrock contact (middle). Transect at 2 m steps. Bottom image is a profile of GPR Line B at Dunbridge with synthetic borehole DUN SBH 2 location and heights shown.

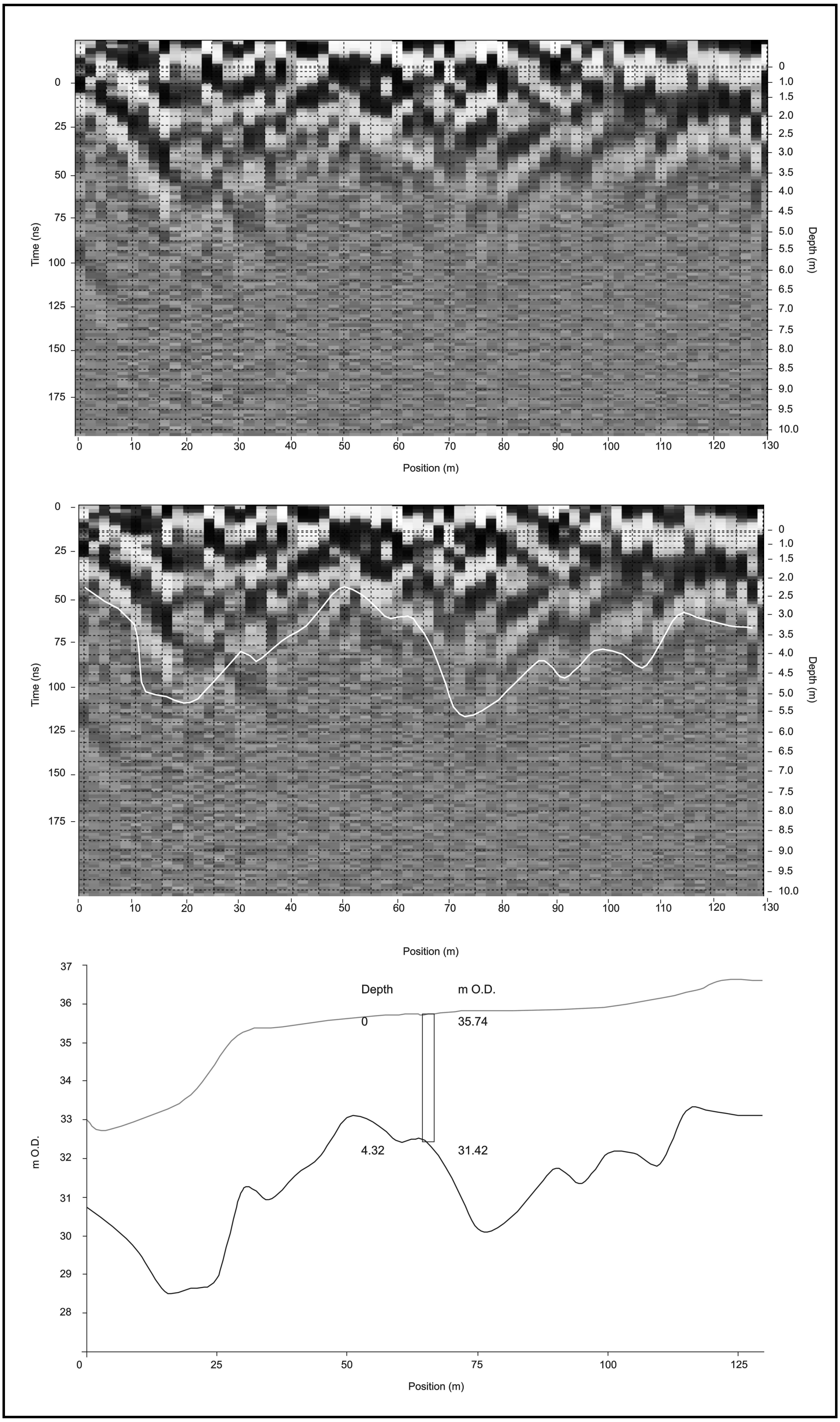


Figure 4.7. West to east GPR trace output of Line C at Dunbridge (SU 3249 2528) (top) with interpretation of bedrock contact (middle). Transect at 2 m steps. Bottom image is a profile of GPR Line C at Dunbridge with synthetic borehole DUN SBH 3 location and heights shown

Table 4.4. Synthetic borehole data generated from GPR transects in the Dunbridge area. The current terrace attributions of PASHCC (Bates *et al*. 2004, 2007; Bates and Briant 2009; Briant *et al*. 2012) and Westaway *et al*. (2006; Harding *et al*. 2012) are shown.

Reference	Easting	Northing	Ground level (m O.D.)	Terrace thickness (m)	Bedrock height (m O.D.)	Terrace PASHCC	Terrace W. *et al*. (2006)
DUN SBH 1	432309	125701	42.10	3.64	38.46	Terrace 5	Belbin (T4)
DUN SBH 2	432498	125332	34.97	4.21	30.76	Terrace 4	Mottisfont (T3)
DUN SBH 3	432490	125289	35.74	4.32	31.42	Terrace 4	Mottisfont (T3)

The three transects are located at the front edge of the Belbin Terrace (Line A) and Mottisfont Terrace (Lines B and C) as mapped by Harding *et al*. 2012 (Figure 4.3). This is reflected in the bedrock elevation differences between the GPR data produced (Table 4.4) and the section data of Harding *et al*. (2012) (Table 4.2). These indicate a slope descending ~5 m from the back to front edges of the Belbin terrace and ~5 m (ground level) to ~7 m (bedrock) of the Mottisfont terrace. It appears likely that GPR lines B and C in particular may be on an eroded terrace edge.

Problematic Ground Penetrating Radar transects

Line D (Figure 4.8a) was 143 m in length, with ground level along the transect between 33.60 m O.D. at the west to 31.57 m O.D. The deepest reflectors can be seen between around 32.5 m and 29.5 m O.D. (a depth of 2.5 to 1 m). This signal is characterised by a series of hyperbolic responses indicative of the location of point targets rather than the clear continuous surface/interface response seen in Lines A to C. The GPR response to the subsurface stratigraphy is unlike that recorded during surveys at Warsash and the Western Solent that are known (by the presence of borehole logs in the vicinity) to be located on terrace gravel deposits. Historic mapping (Davies 2013) indicates that the Kimbridge Quarry to the south may have extended into this location and as such the Pleistocene deposits may not remain. It seems likely that there are no *in situ* deposits recorded in Line D.

Line E (Figure 4.8b) was 70 m in length, with ground level along the transect between 35.20 m O.D. at the west to 32.20 m O.D. The deepest reflector can be seen between around 32.5 m and 29.5 m O.D. (a depth of 2.5 to 1 m). The signal is of a lower resolution to that of Line D (30 m to the north) due to the increased step size of the transect. The signal below this depth, however, appears to show some responses that may be interpreted as weak hyperbolic signals as in Line D, 30 m to the north. It is not clear that there are *in situ* deposits recorded in Line E.

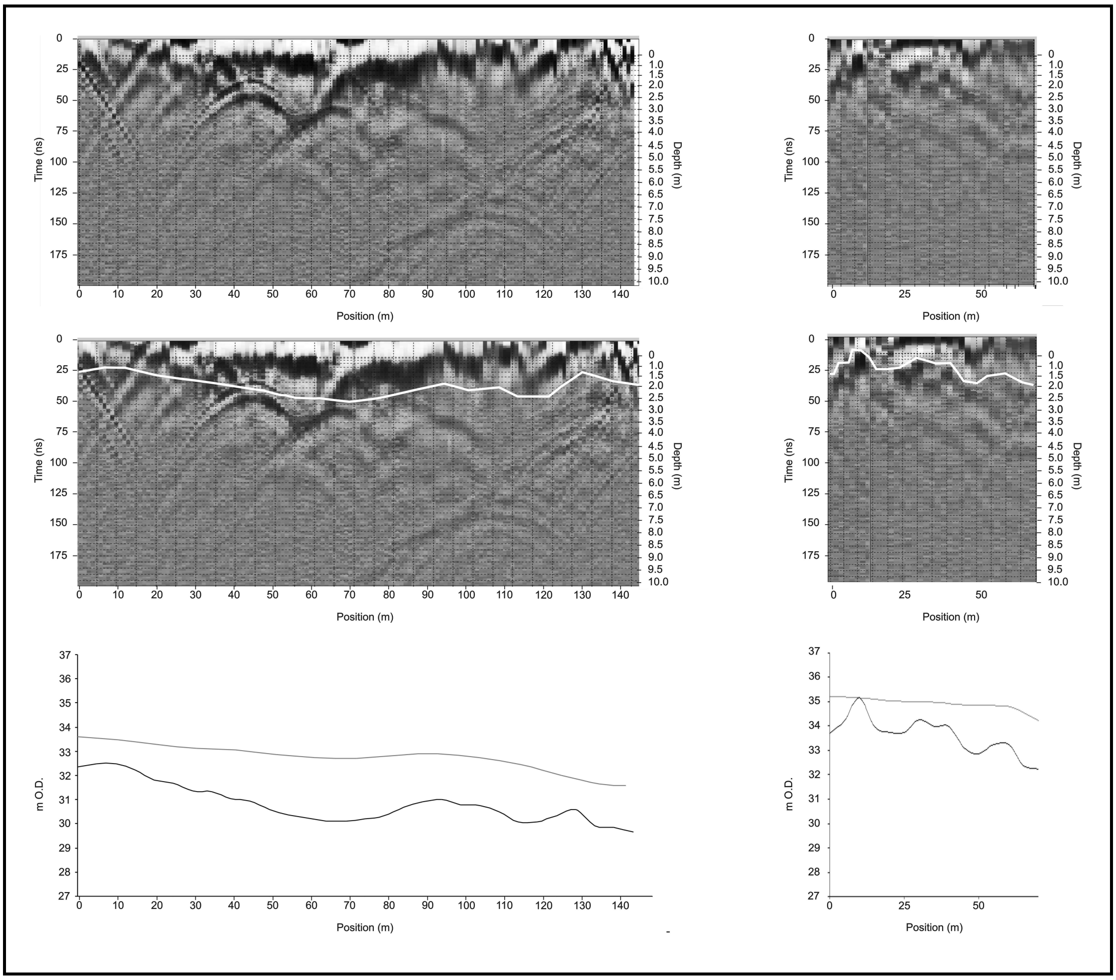


Figure 4.8. West to east GPR trace output of a) Line D (SU 3253 2519) and b) Line E (SU 3250 2517) at Dunbridge (top) with interpretation of bedrock contact (middle) (transect at 1 m steps). Bottom image is a profile of GPR Lines E and D at Dunbridge.

Lines F, G, H, and I were carried out in the same field, south of Berry's Pond (Figure 4.4, above), using the wheeled pulseEKKO PRO smartcart. The trace outputs (Figure 4.9) show little variation in the signal along the majority of each transect, with no surface/interface responses detected. The lack of signal response indicates a uniformity of the subsurface stratigraphy unlike the response to gravels seen elsewhere. Hyperbolic responses of varying strength and depth can be seen towards the end of each transect. Harding *et al*. (2012, figures 2 and 8) show test pits and boreholes in the locality of GPR lines F, G, H & I but do not record either the Belbin or Mottisfont terrace extending into the area. This would suggest that gravels were not present, and as such the GPR survey may have recorded bedrock alone.

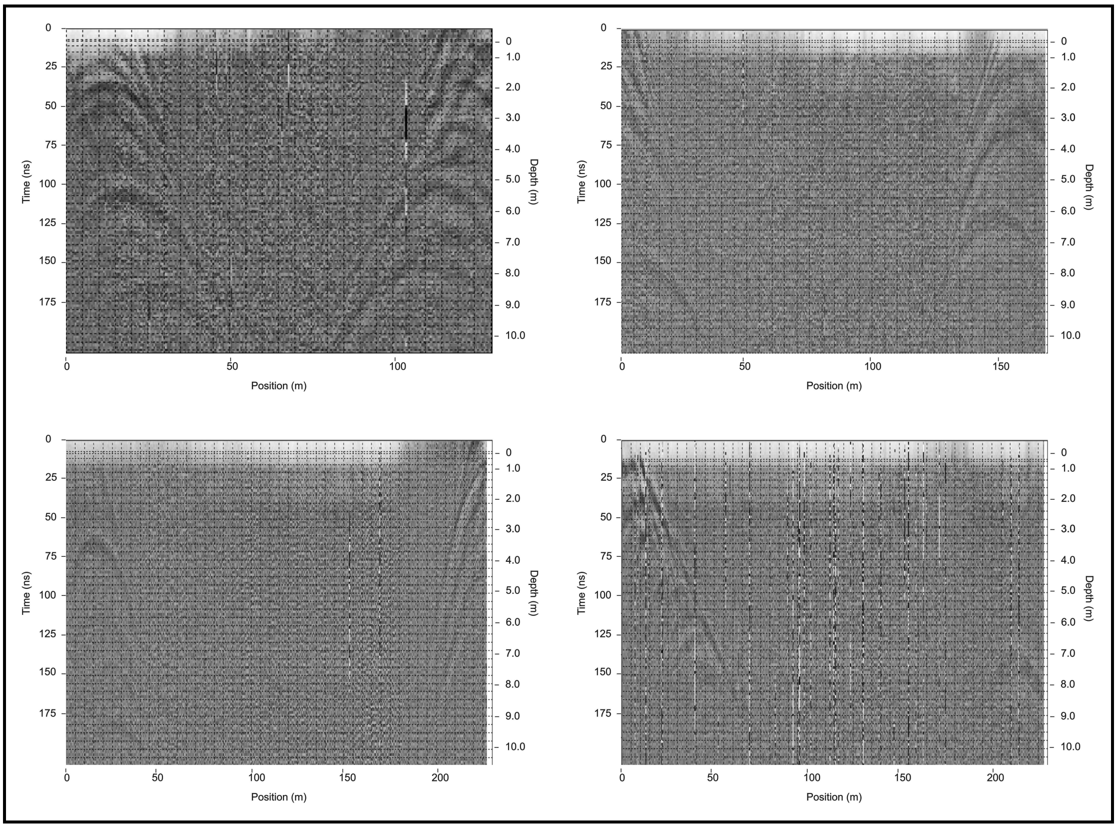


Figure 4.9. West to east GPR trace outputs of Lines F (SU 3222 2511), G (SU 3222 2507), H (SU 3219 2504) and I (SU 3218 2500) at Dunbridge (using smartcart).

4.3 Warsash

Warsash is located at the confluence of the River Hamble and River Test (Figure 4.10), and lies upon Pleistocene fluvial deposits formed by the latter. Edwards and Freshney (1987) mapped these as predominantly Terrace 3 with areas of Terrace 2. To the east there are spreads of Terrace 4 and 5 deposits and to the north Terrace 6. The orientation of the terrace geomorphology shows a north-east to south-west trending migration of the Pleistocene Test which flowed to the south-east. In the Warsash area, access to *in situ* fluvial deposits was provided at the perimeter of two disused quarries, which in turn provided samples suitable for OSL. GPR surveys were also carried out along with examination of the borehole archive of the region.

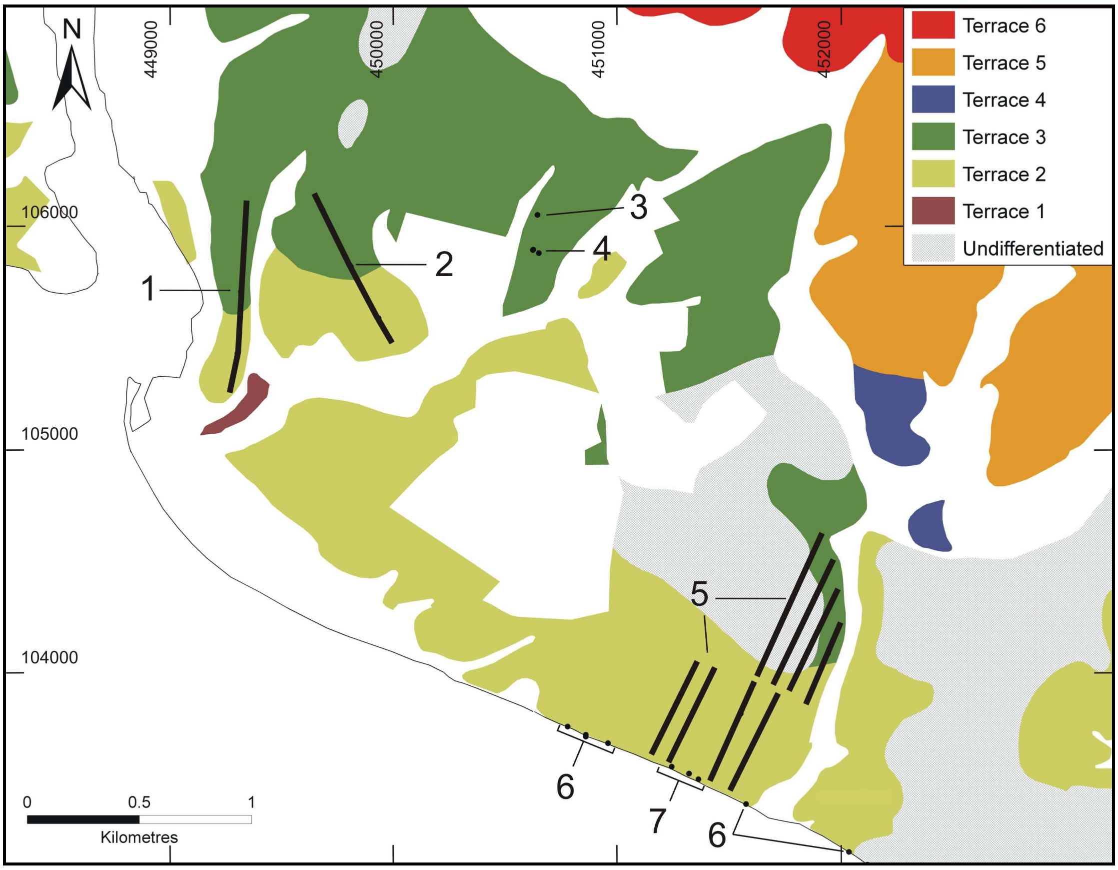


Figure 4.10. Location map of fieldwork sites and terrace attributions (Edwards and Freshney 1987) in the Warsash area. Brickearth is shaded grey. Fieldwork sites are numbered: 1. Newtown Road (GPR). 2. Church Road (GPR). 3. Hamble Park (excavation of quarry sections and OSL). 4. Warsash Common quarries (excavation of quarry sections and OSL). Nearby fieldwork locations (see below): 5. Chilling Copse (GPR). 6. Solent Breezes (coastal section recording). 7. Brownwich Lane (coastal section recording and OSL).

4.3.1 Previous work: Warsash

The only previous published work on the immediate Warsash area are two short papers on Palaeolithic tools found in the region (Burkitt *et al*. 1939; Shackley 1970) (Figure 4.11). The former paper provides a brief interpretation of the sediments at one of the gravel pits excavated in the area, Newbury's Pit, along with the description of a section face. No precise location detail for the four pits is provided, nor is the pit section described in the text identified. The only geographical information provided places the four gravel pits to the east of Warsash towards Hook and 'between 100 and 200 feet above the level of Southampton Water', and names the sites as New Pit, Park's Pit, Dyke's Pit and Newbury's Pit.

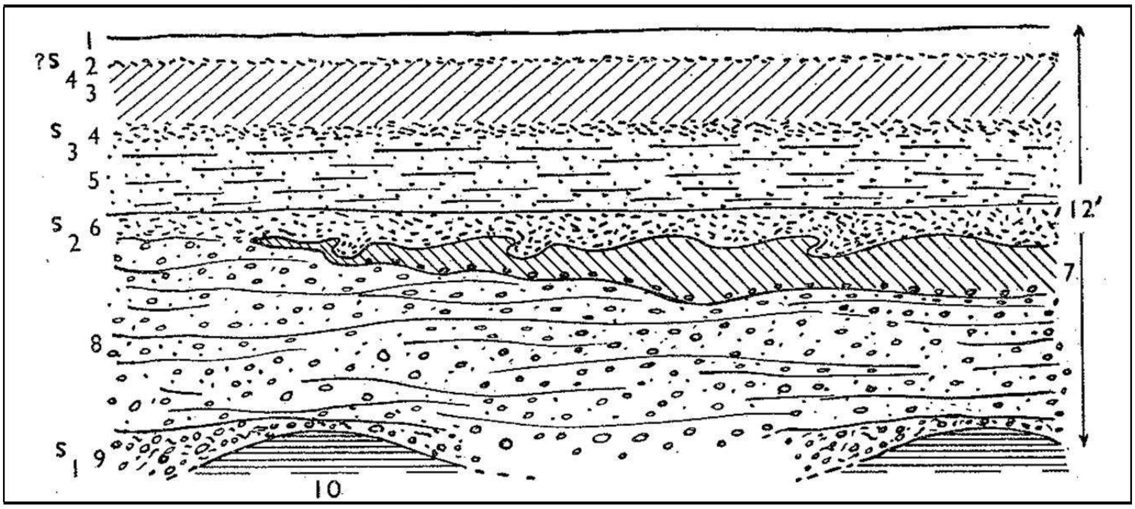


Figure 4.11. Section in Newbury’s Pit gravel quarry recorded by Burkitt *et al.* (1939).

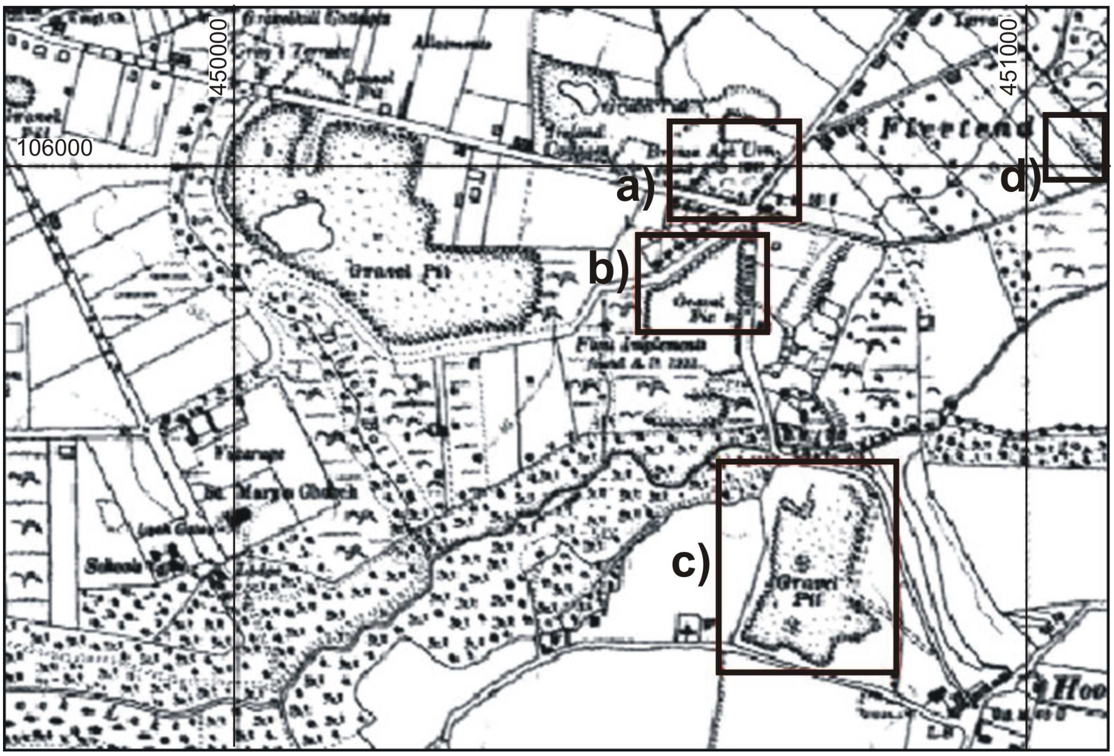


Figure 4.12. Location map of a) Park’s Pit, b) Dyke’s Pit, c) Newbury’s Pit and d) Fleet End Pit.

A recent survey of former gravel pit locations which produced significant archaeological find-spots (Davies 2013) revealed four locations in the Warsash area which could potentially retain *in situ* deposits around the perimeter of the quarried area (Figure 4.12), Park’s Pit, Dyke’s Pit, Newbury’s Pit and Fleet End Pits. The footprint of Newbury’s Pit has since been filled-in, with the former quarry location currently used to hold livestock. There were no opportunities in the area to locate or excavate the former quarry perimeter. Fleet End Pit was located, although it was not possible to gain permission to excavate the site. Permission was granted however to carry out a small scale auger-hole survey by hand nearby. This survey attempted to locate the substantial brickearth deposit identified by Burkitt *et al.* (1939) in the Warsash area, but this was not found in the top c.1 m of sediment augered.

Fieldwork was undertaken at locations at Hamble Park (SU 506 060) (HAP10 S1) and Warsash Common (SU 506 058) (WAC10 S1), the former sites of Park's Pit and Dyke's Pit respectively (Figure 4.13), in order to expose *in situ* deposits mapped as Terrace 3 of the River Test. A single section was hand dug and recorded at each location. Sedimentary interpretations follow Miall (1996) as modified by Briant (2002).

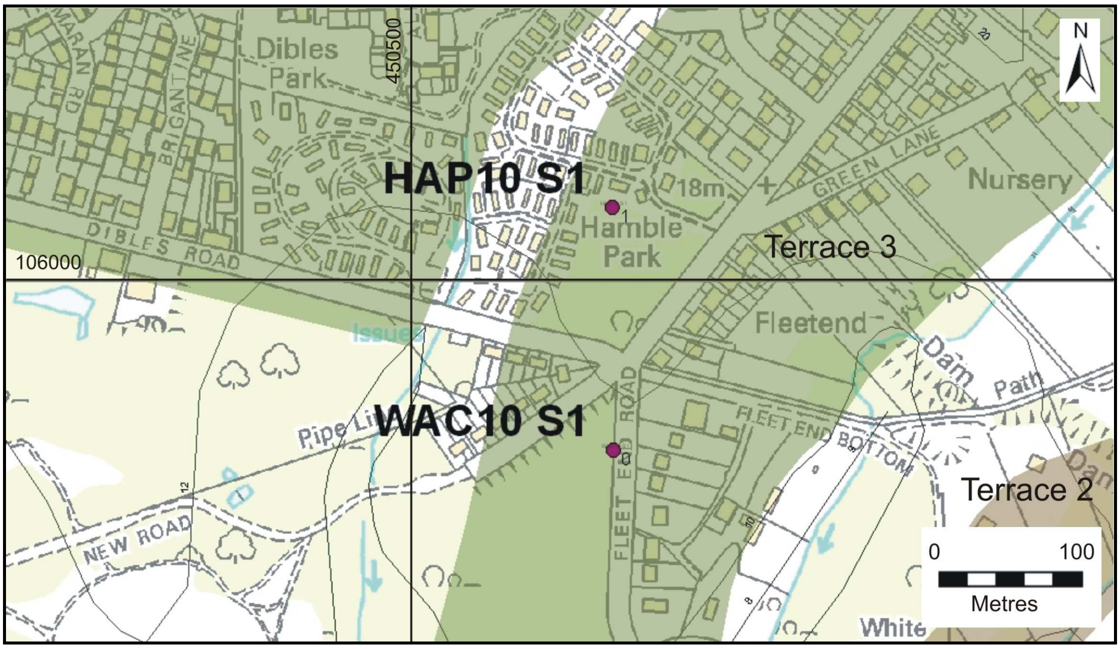
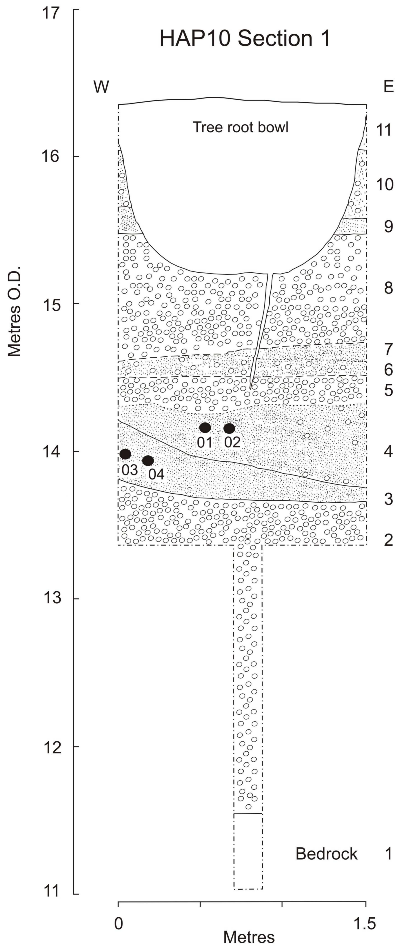


Figure 4.13. Location of quarry sections excavated at Hamble Park (HAP10 S1) and Warsash Common (WAC10 S1).

4.3.2 Stratigraphy and sedimentology: Hamble Park



Bed no.	Facies code	Facies assoc.
10	Gh	C
09	Sh	
08	Gh	
07	Sm	
06	Sh	
05	Gh	
04	Sh	B
03	Sh	
02	Gh	A

Figure 4.14. Lithofacies and facies associations proposed for section HAP10 S1 at Hamble Park quarry. OSL sample locations are numbered 01 – 04.

The section recorded in Hamble Park (Figure 4.14; Tables 4.5 and 4.6) has three identifiable sedimentary units from base to top:

Facies Association A

Facies association A (Figure 4.14) comprises a single deposit of horizontally bedded, clast supported, flint-dominated gravel. Clasts are sub-angular to sub-rounded. The matrix is medium to coarse slightly silty sand. The unit is concreted, with an iron-pan layer 5 to 10 cm below the top of the deposit. The unit was exposed to around 0.3 m in thickness. The lower bounding surface with bedrock was not reached in the section but bedrock was located by use of a hand-held auger (Figure 4.14).

Facies Association B

Facies B (Figure 4.14) comprises two sand beds which are possibly separated by a concave-up 2nd order (coset) bounding surface. The lower bed is a moderately compact fine sand with a slightly clayey band and patches, displaying sub-parallel bedding aligned with the lower boundary. The upper bed is a friable medium sand with some horizontal bedding, slightly gravelly in the right of the section. The unit has some iron-staining, and is around 0.59 m in thickness. Facies B fills a channel or scour cut into Facies A, the extent of which cannot be determined due to the limited exposure. The lower bounding surface is a concave-up 4th or 5th order erosional contact.

Facies Association C

Facies C (Figure 4.14) consists of a sequence of gravelly and sandy bedform accumulation, possibly representing stacked gravel bars. The basal gravel is clast-supported with some crude horizontal bedding, with flint-dominated sub-angular to sub-rounded clasts. This bed is overlain by a sandy bedform, often indicative of a bar-top (Bryant 1993). The lower sand deposit is horizontally bedded, however any lamination in the upper sand deposit has not been preserved. Further gravel bar/bedform accumulation follows, with a deposit of clast-supported very fine to coarse, sub-angular to sub-rounded, flint-dominated gravel with some crude horizontal bedding. A thin (c.13 cm) horizontally bedded sand bed again overlies the gravel bedform, which in turn is overlain by a final (iron-stained) clast-supported flint gravel. The unit has some iron-staining and is around 1.66 m in thickness. As the section is two-dimensional there is no way of determining the geometry of any potential gravel bar formation. The upper two deposits of the section are truncated by a modern tree-root bowl, limiting their exposure at this location. The lower bounding surface is a flat 3rd order reactivation contact.

Table 4.5. Characteristics of the lithofacies associations at HAP10 S1.

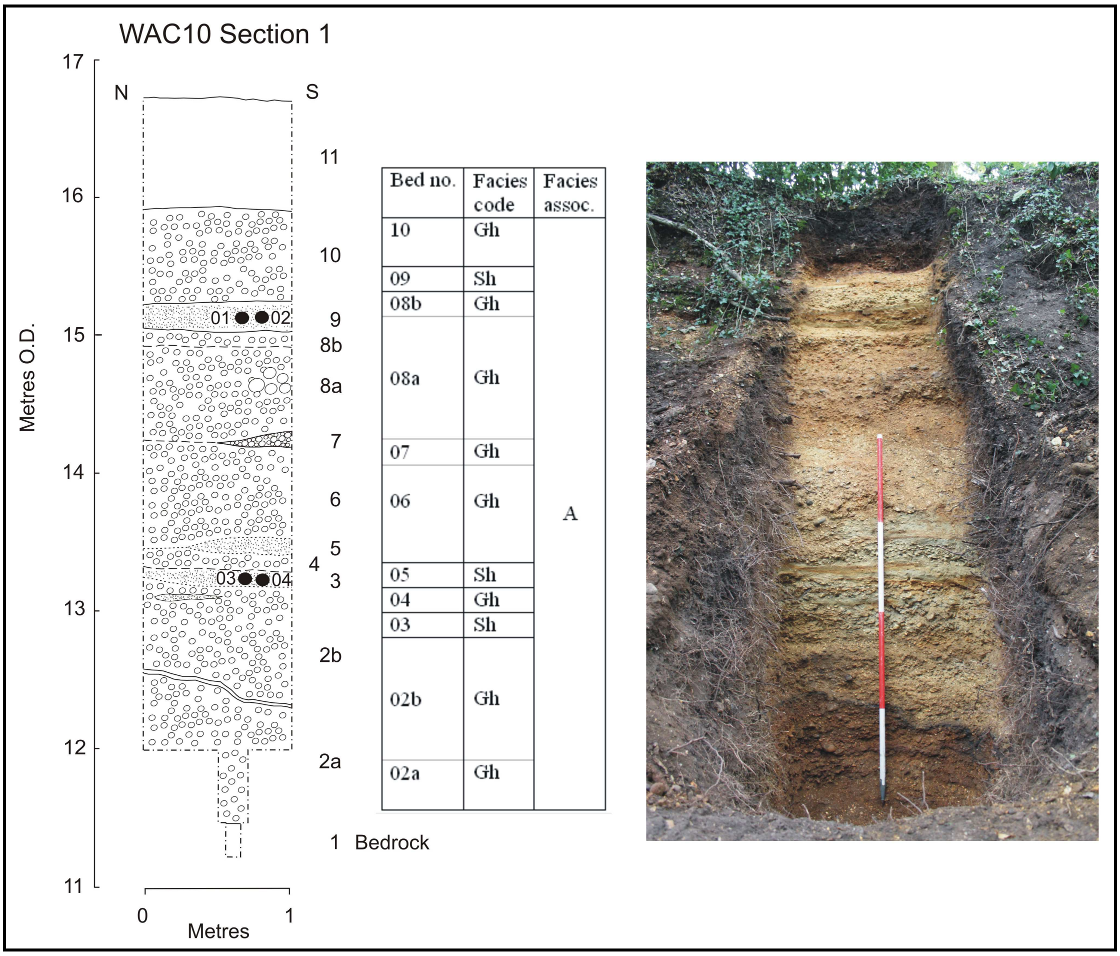
Lithofacies Association	Lithofacies	Lower Bounding Surface
C	Gh, Sh, Sm	Flat, 3rd order
B	Sh	Concave-up, 4th or 5th order
A	Gh	unknown

Table 4.6. Sedimentary description of section HAP10 S1 excavated at Hamble Park (NGR 450641, 106051).

Bed	Description	Depth top	m O.D.	Th.
11	TOPSOIL	0.00	16.27	0.41
10	SANDY GRAVEL. Fine to medium gravel, sub-angular to sub-rounded; clast supported; some horizontal bedding; slightly silty, medium to coarse matrix; iron-stained; moderately sorted; moderately compact; sharp lower boundary.	0.41	15.86	0.49
09	SAND. Medium to coarse, some horizontal bedding; slightly silty; some iron staining; [2.5Y 7/4]; pebble trail c.6cm from top with slightly clayey band; gradational lower boundary.	0.90	15.37	0.13
08	SANDY GRAVEL. Very fine to coarse gravel with occasional cobbles, sub-angular to sub-rounded; moderately sorted; clast supported; some horizontal bedding; medium to coarse matrix; some iron staining in top 10cm and around roots; moderately compact; [2.5Y 3/2]; conformable lower boundary.	1.03	15.24	0.72
07	SAND. Medium to coarse, iron-stained; massive; gradational lower boundary.	1.75	14.52	0.10
06	GRAVELLY SAND. Medium to coarse sand (as above) with some medium to fine gravel; [2.5Y 7/5]; some crude horizontal bedding; conformable lower boundary.	1.85	14.42	0.06
05	SANDY GRAVEL. Fine to coarse gravel with occasional cobbles; sub-angular to sub-rounded; poorly sorted; clast supported; some crude horizontal bedding; medium matrix; loose/friable; [2.5Y 7/5]; gradational lower boundary.	1.91	14.36	0.16
04	SAND. Medium, some iron staining, slightly gravelly in right of bed; loose/friable; [2.5Y 7/4]; some horizontal bedding; sharp/erosional lower boundary.	2.07	14.20	0.53
03	SAND. Fine, with slightly clayey grey [2.5Y 7/1] band and patches; some iron staining; [2.5Y 7/3] at top, [2.5Y 8/4] lower; sub-parallel bedding aligned with lower boundary; moderately compact; sharp/erosional lower boundary.	2.60	13.67	0.06
02	SANDY GRAVEL. Fine to coarse gravel with occasional cobbles, sub-angular to sub-rounded; poorly sorted; clast supported; horizontally bedded; slightly silty medium to coarse matrix; compact; iron pan layer 5 to 10 cm from top of strata; iron-stained.	2.66	13.61	2.14
01	BEDROCK. Clay bedrock, fine.	4.80	11.47	1.00
	Base of section	5.80	10.47	

4.3.3 Stratigraphy and sedimentology: Warsash Common

The restricted width of the section recorded at Warsash Common (Figure 4.15; Table 4.8) quarry combined with a lack of diagnostic features make determining facies associations here difficult, although its lithological characteristics appear similar to HAP10 S1 (above). The section was recorded as a single facies association (Table 4.7).



Bed no.	Facies code	Facies assoc.
10	Gh	A
09	Sh	
08b	Gh	
08a	Gh	
07	Gh	
06	Gh	
05	Sh	
04	Gh	
03	Sh	
02b	Gh	
02a	Gh	

Figure 4.15. Lithofacies and facies associations proposed for section WAC10 S1 at Warsash Common quarry. OSL sample locations are numbered 01 – 04.

Facies Association A

Facies association A (Figure 4.15) overlies bedrock above an erosional unconformity and consists of a sequence of gravelly and sandy bedform elements, possibly representing stacked gravel bars. The lower gravels are clast supported with very fine to coarse clasts, fining downward towards the base of the section. The upper 1.4 m of gravels are of fine to medium clasts, generally coarsening downward. The basal gravel is concreted with an iron-pan layer at the top of the deposit, similar to the basal gravel bed at Hamble Park quarry. The bed is c.0.9 m lower in this section. The gravel bedforms are separated by medium to coarse sandy bedforms with some horizontal bedding, again possibly indicative of bar-tops. Each of the gravel beds recorded were dominated by flint clasts. As the section is two-dimensional there is no way of determining the geometry of any potential gravel bar formation. The unit has some iron-staining and is around 4.26 m in observed thickness.

Table 4.7. Characteristics of the lithofacies association in WAC10 S1.

Lithofacies Association	Lithofacies	Lower Bounding Surface
A	Gh, Sh	Flat, 5th order

Table 4.8. Sedimentary description of section WAC10 S1 excavated at Warsash Common (NGR 450647, 105881).

Bed	Description	Depth top	m O.D.	Th.
11	TOPSOIL.	0.00	16.56	0.74
10	SANDY GRAVEL. Fine to medium gravel; sub-angular to rounded; clast supported; some crude horizontal bedding; moderately sorted; medium to coarse matrix; [7.5YR 6/8] or iron stained in top half, [2.5Y 8/4] in lower half; sharp lower boundary.	0.74	15.82	0.60
09	SAND. Medium sand; some horizontal bedding; some iron stained bands; pebble trail 2/3 of way down; [2.5Y 7/2]; sharp lower boundary.	1.34	15.22	0.21
08b	SANDY GRAVEL. Fine to medium gravel; sub-angular to rounded; moderately sorted; clast supported, almost open framework; horizontally bedded; medium to coarse matrix; fine to medium matrix; [2.5Y 8/4]; conformable lower boundary.	1.55	15.01	0.10
08a	SANDY GRAVEL. Slightly clayey; fine to coarse gravel; sub-angular to rounded; poorly sorted; clast supported; some crude horizontal bedding; clasts coarsening downward; [2.5Y 7/2]; sharp to conformable lower boundary.	1.65	14.91	0.57
07	GRAVEL. Very fine to medium gravel; sub-angular to rounded; open framework; sharp lower boundary.	2.22	14.34	0.10
06	SANDY GRAVEL. Very fine to coarse gravel; sub-angular to rounded; poorly sorted; clast supported; some crude horizontal bedding; clasts coarsening downward; medium to coarse matrix; [7.5YR 6/8] in top 20cm, [2.5Y 8/2] below; gradational lower boundary.	2.32	14.24	0.64
05	SAND. Medium to coarse sand; some horizontal bedding; some iron staining; [7.5YR 7/2]; gradational lower boundary.	2.96	13.60	0.11
04	SANDY GRAVEL. Very fine to medium gravel; sub-angular to sub-rounded; well sorted; clast supported; horizontally bedded; coarsening downward; [7.5YR 7/2]; conformable lower boundary.	3.07	13.49	0.12
03	SAND. Medium to coarse sand; some horizontal bedding; some iron staining; [7.5YR 7/2]; gradational lower boundary.	3.19	13.37	0.10
02b	SANDY GRAVEL. Very fine to coarse gravel; sub-angular to rounded; clast supported; moderately sorted; medium to coarse matrix; some horizontal bedding; horizontal band of open framework very fine to fine gravel at c.3.52m; clasts fining downward from below c.3.6m; [7.5YR 6/6]; sharp lower boundary.	3.29	13.27	0.70
02a	Fe STAINED SANDY GRAVEL. Very fine to coarse gravel; sub-angular to rounded; clast supported; moderately sorted; medium to coarse matrix; some horizontal bedding; iron-pan at top; almost open framework in places; compact/concreted; erosional lower boundary.	3.99	12.57	1.01
01	BEDROCK. Clay bedrock, fine.	5.00	11.56	1.00
	Base of section	6.00	10.56	

4.3.4 Ground Penetrating Radar: Warsash

GPR surveys were carried out in two locations around Warsash using the pulseEKKO PRO smartcart; Newtown Road and Church Road in Warsash itself (Figure 4.16) and Solent Breezes/Chilling Copse to the south-east of the town (section 4.4, below). Both areas contained Terraces 2 and 3 as currently mapped and provided the opportunity to further contextualise fieldwork at Hamble Park and Warsash Common.

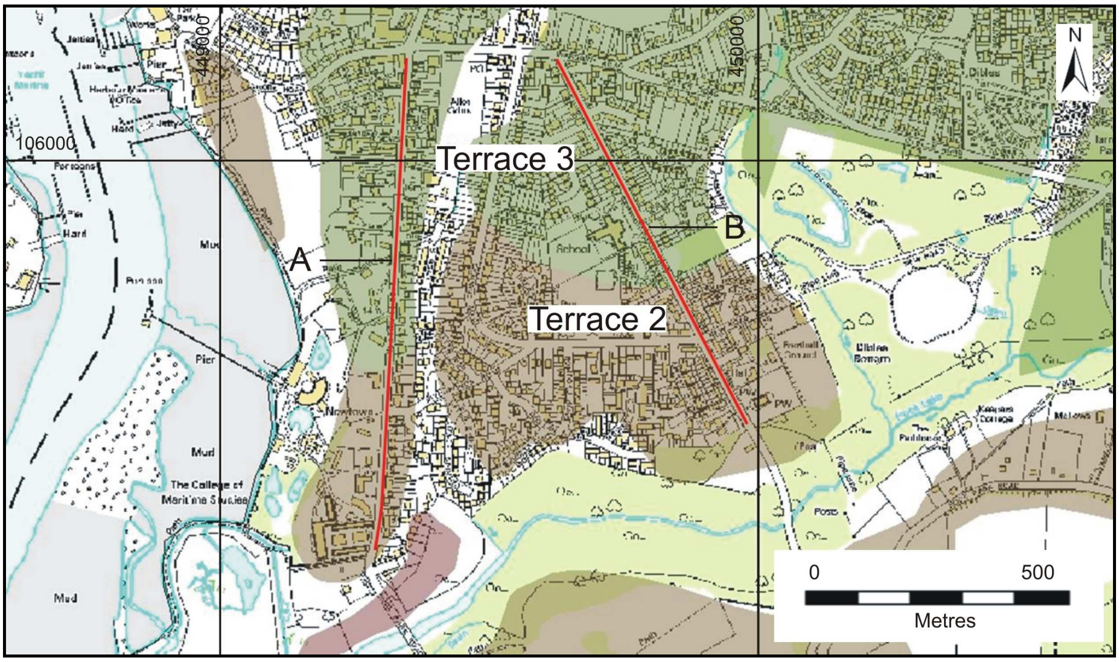


Figure 4.16. Location of GPR transects carried out in the Warsash area. A) Newtown Road and B) Church Road.

The GPR transect at Newtown Road (SU 4934 0603) (Figure 4.17) shows two bluff features in the ground level with corresponding breaks of slope in the bedrock. Surface height along the first 310 m of the transect is at around 16 m, with the bedrock surface at around 13 m. Ground level then drops to around 14 m with bedrock between 10 and 11 m. At 600 m the last break in profile sees ground level at 12 m with bedrock at 8 m. The lowest terrace then erodes into a stream valley from 825 m along the transect.

Newtown Road

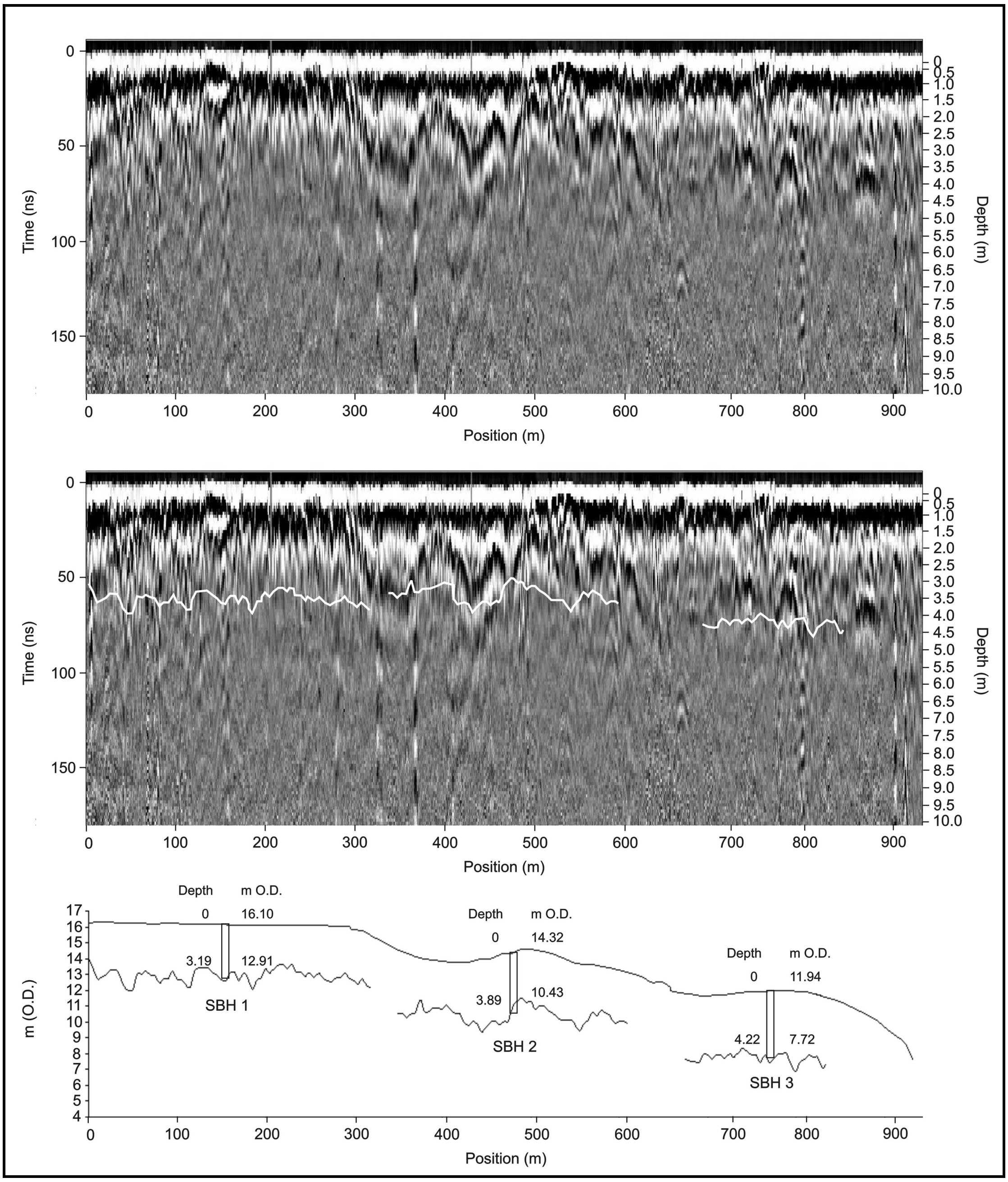


Figure 4.17. North to south GPR trace output of Newtown Road (top) with interpretation of bedrock contact (middle). Bottom image is a profile of the GPR transect with synthetic boreholes NTRD SBH 1, 2 and 3 locations.

Church Road

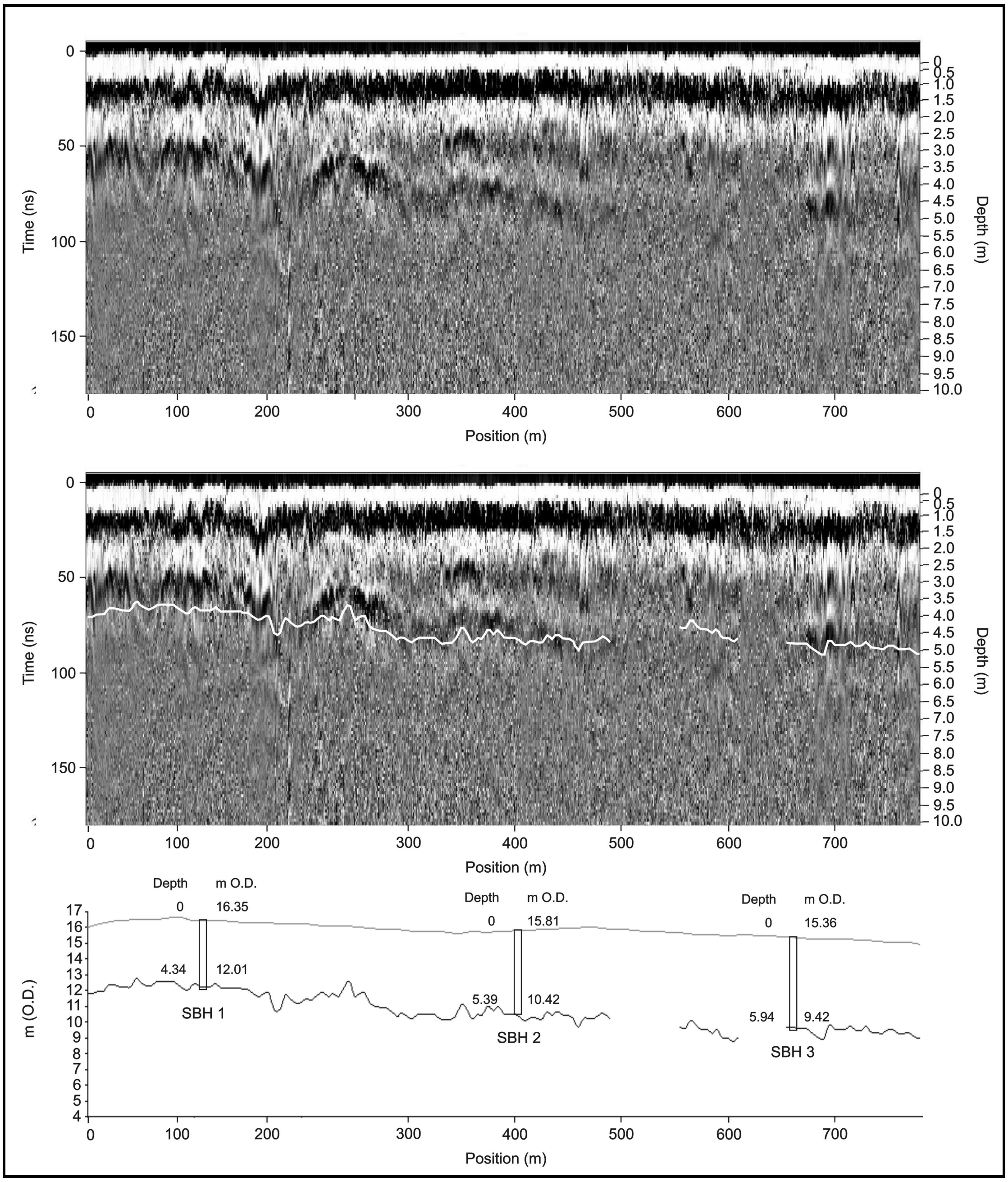


Figure 4.18. North to south GPR trace output of Church Road (top) with interpretation of bedrock contact (middle). Bottom image is a profile of the GPR transect with synthetic boreholes CHRD SBH 1, 2 and 3 locations.

The topography of the second transect at Church Road (SU 4968 0607) (Figure 4.18), east of Newtown Road, shows a similar profile for the first 600 m, with a single break of slope at around 250 m. Ground level differed by less than two metres (16.62 m to 14.95 m) over a consistent gradient along the length of the transect, while the corresponding bedrock surface ranges from 12.79 m to 8.75 m. The second break of bedrock profile present at Newtown Road is not seen at Church Road; rather there appears to be a gently sloping bedrock surface towards the front edge of Terrace 3. The breaks in profile seen at Newtown Road are however comparable to those seen in the Terrace 2 and 3 borehole logs at Warsash (see Figure 4.37 below).

Table 4.9. Synthetic borehole data generated from GPR transects in the Warsash area. The current terrace attributions of Edwards and Freshney (1987) and Westaway *et al*. (2006) are shown.

Reference	Easting	Northing	Ground level (m O.D.)	Terrace thickness (m)	Bedrock height (m O.D.)	Terrace E. & F. (1987)	Terrace W. *et al*. (2006)
NTRD SBH 1	449340	106030	16.10	3.19	12.91	Terrace 3	Belbin (T4)
NTRD SBH 2	449320	105711	14.32	3.89	10.43	Terrace 3	Belbin (T4)
NTRD SBH 3	449304	105434	11.94	4.22	7.72	Terrace 2	Hamble (T2)
CHRD SBH 1	449684	106073	16.35	4.34	12.01	Terrace 3	Belbin (T4)
CHRD SBH 2	449810	105821	15.81	5.39	10.42	Terrace 3	Belbin (T4)
CHRD SBH 3	449933	105591	15.36	5.94	9.42	Terrace 2	Hamble (T2)

4.4 Solent Breezes and Chilling Copse

Solent Breezes (SU 5077 0377) is located on the eastern side of Southampton Water, around 2 km south of Warsash. Chilling Copse (SU 5176 0420) is situated just downstream, around 600 m inland of the coast. The exposed coastal deposits in the area are of Terrace 2, with the transition to Terrace 3 occurring around Chilling Copse. A reconnaissance survey of undeveloped coastal areas between Solent Breezes and Lee-on-Solent identified several locations with potentially *in situ* fluvial deposits exposed (see Figure 4.10 above). Sections were scanned using an Imaging Station and a sedimentary log was recorded where access was possible. Ground penetrating surveys were also carried out around Chilling Copse.

4.4.1 Previous work: Solent Breezes and Chilling Copse

The PASHCC project produced OSL ages for Terrace 2 at Solent Breezes, brickearth overlying Terrace 3 at Chilling Copse and for Terrace 5 at Hook (Table 2.4; Chapter 7.7). Stratigraphic data was recorded at ten locations in the Test Valley (Table 4.16), and was included in this study. Data and OSL samples from coastal sections from previous studies at Brownwich were also made available.

4.4.2 Stratigraphy and sedimentology: Solent Breezes

The fluvial sands and gravels seen in the coastal section at Solent Breezes are out of reach from the modern beach level. The only access to the deposits was afforded by a slumped section face near the section SOB10 S2 at the site of modern erosion taking place to the coast. Sedimentary log SOB L2 (Table 4.10, Figure 4.19) was recorded in as much detail as was possible with limited access.

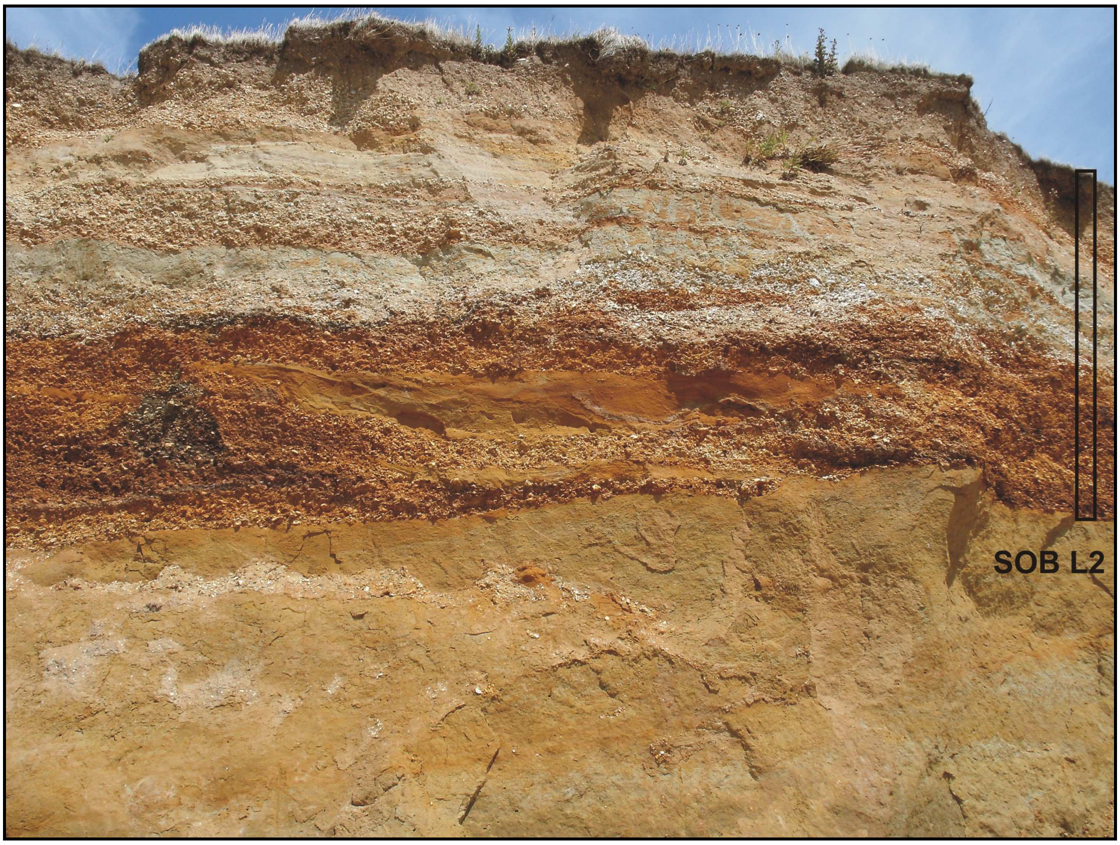


Figure 4.19. Location of sedimentary log SOB L2.

Table 4.11 shows ground level, gravel terrace thickness and bedrock height data generated from imaging station recording of coastal sections SOB10 S1 to S5 at Solent Breezes. Synthetic boreholes SBH 1 to 5 summarise the stratigraphy of the coastal sections.

Table 4.10. Sedimentary log SOB L2.

Bed	Description	Depth top	m O.D.	Th.
1	TOPSOIL.	0.00	9.34	0.43
2	SANDY GRAVEL. Fine to coarse gravel; poorly sorted; clasts sub-angular to sub-rounded; medium sand matrix. [out of reach]	0.43	8.91	0.84
3	SAND. Slightly clayey fine to medium sand (as bed 5). [out of reach]	1.27	8.07	0.47
4	SANDY GRAVEL. Fine to coarse gravel; poorly sorted; clasts sub-angular to sub-rounded; medium sand matrix. [out of reach]	1.74	7.60	0.48
5	SAND. Slightly clayey fine to medium sand; no apparent bedding. [out of reach]	2.22	7.12	0.40
6	SANDY GRAVEL. iron stained fine to coarse gravel; moderately sorted; clasts sub-angular to sub-rounded; fine/fine to medium sand matrix.	2.62	6.72	0.88
7	SAND. Fine to medium sand; reddish yellow; massive/ structureless. [Barton Sand]	3.50	5.84	1.00
	End of log	4.50		

Table 4.11. Synthetic borehole data from Imaging Station sections and log at Solent Breezes. The current terrace attributions of Edwards and Freshney (1987) and Westaway *et al*. (2006) are shown.

Reference	Easting	Northing	Ground level (m O.D.)	Gravel thickness (m)	Bedrock height (m O.D.)	Terrace E. & F. (1987)	Terrace W. *et al*. (2006)
SOB SBH1	450775	103775	9.08	2.46	6.36	Terrace 2	Hamble (T2)
SOB SBH2	450856	103738	8.90	2.80	5.85	Terrace 2	Hamble (T2)
SOB SBH3	450955	103701	9.43	1.54	7.66	Terrace 2	Hamble (T2)
SOB SBH4	451570	103430	9.37	1.43	7.64	Terrace 2	Hamble (T2)
SOB SBH5	452110	103160	9.27	2.37	6.55	Terrace 2	Hamble (T2)
SOB L2	450856	103730	9.34	3.07	5.84	Terrace 2	Hamble (T2)

SOB10 S1 to S3 (Figure 4.20) provides around 270 m of near-continuous stratigraphic data in the coastal section. SOB10 S4 and S5 (Figure 4.21) were recorded 300 to 400 m further downstream. The five coastal sections extend over ~1.4 km of exposures of sands and gravels of Terrace 2 at Solent Breezes. The vertical range of bedrock heights recorded along that distance, and in particular the range seen in each individual section, highlight the variety present in bedrock surface topography.

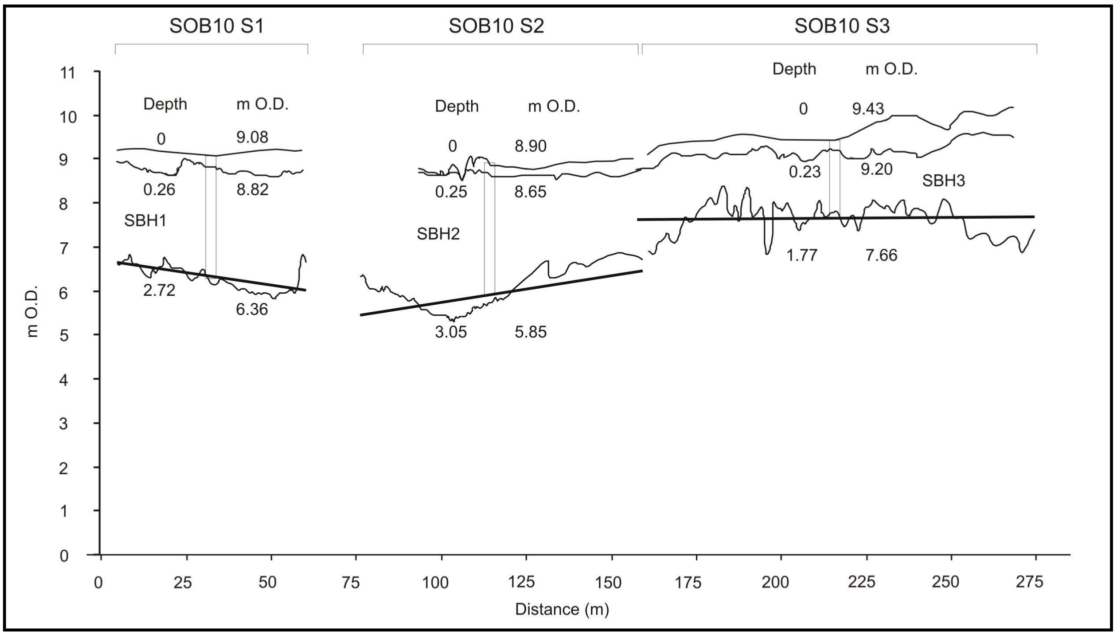


Figure 4.20. Bedrock height (with trend line), terrace surface height and ground level of coastal sections SOB10 S1, S2 and S3 recorded at Solent Breezes. Synthetic borehole SOB SBH 1, 2 and 3 location and heights also shown. The terrace is attributed to Terrace 2 (Edwards and Freshney 1987)/ Hamble (Westaway *et al*. 2006).

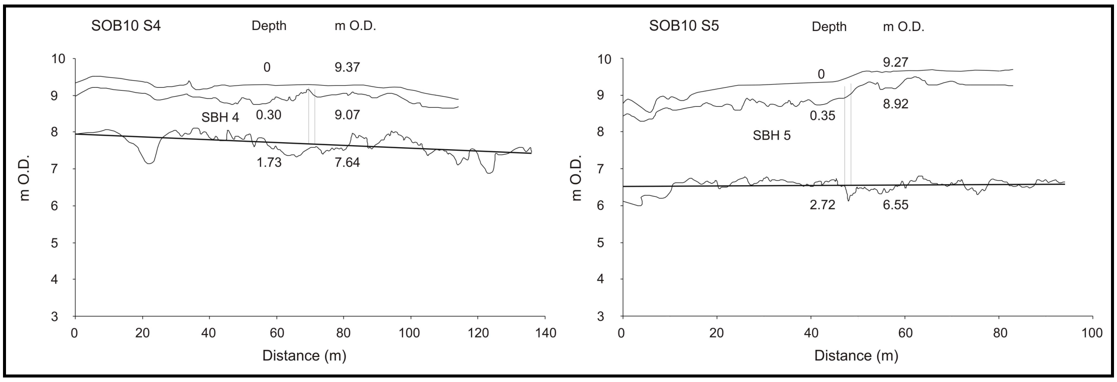


Figure 4.21. Bedrock height (with trend line), terrace surface height and ground level of coastal sections SOB10 S4 and S5 recorded at Solent Breezes. Synthetic borehole SOB SBH 4 and 5 locations and heights also shown. The terrace is attributed to Terrace 2 (Edwards and Freshney 1987)/ Hamble (Westaway *et al*. 2006).

4.4.3 Ground Penetrating Radar: Solent Breezes and Chilling Copse

To complement the GPR survey of Terraces 3 to 2 carried out at Warsash (Newtown Road and Church Road, above), a further survey was carried out in the area between Chilling Copse and Solent Breezes (Figure 4.22). The survey was situated in order to both locate the transition between Terraces 3 to 2 and also to provide a larger dataset of the Terrace 2 bedrock topography and terrace thickness. Eight transects were carried out, Lines A to G, generating synthetic boreholes 1 to 8 respectively (Table 4.12). A similar profile was seen in each of the transects. An example of the profile produced from Terrace 3 to Terrace 2 can be seen in Figure 4.23.

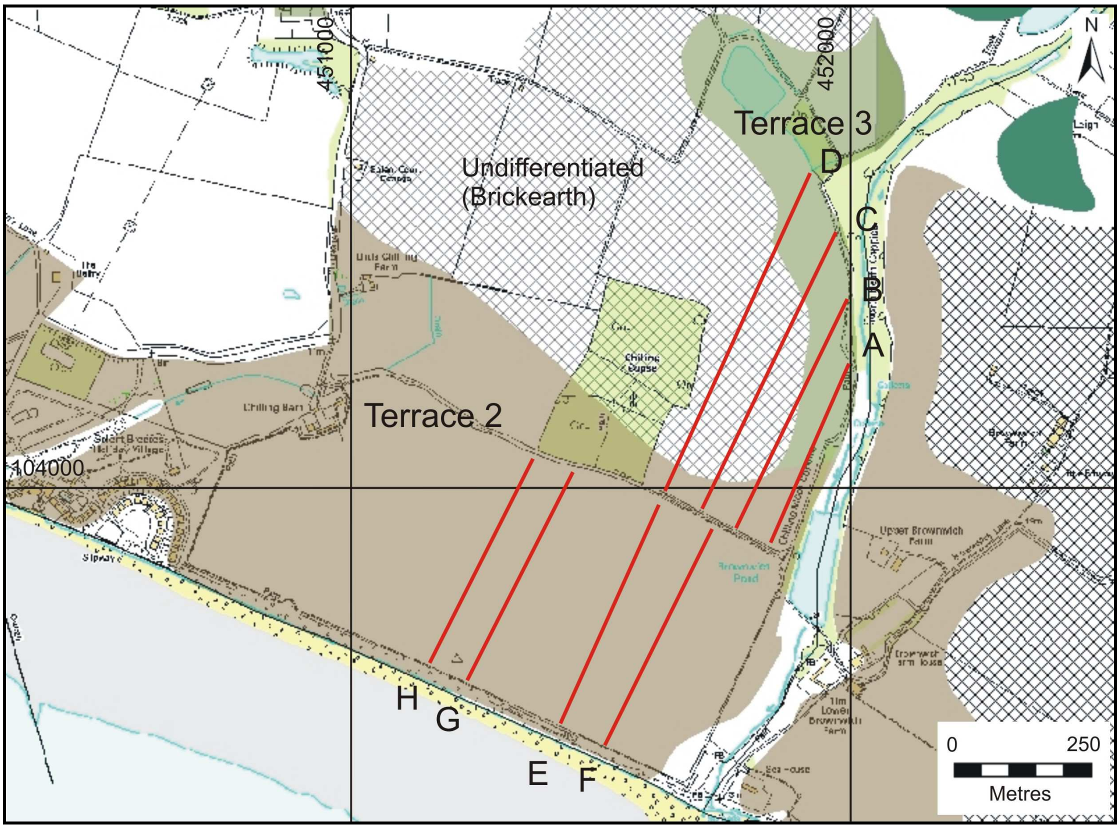


Figure 4.22. Location of GPR transects carried out in the Solent Breezes/Chilling Copse area.

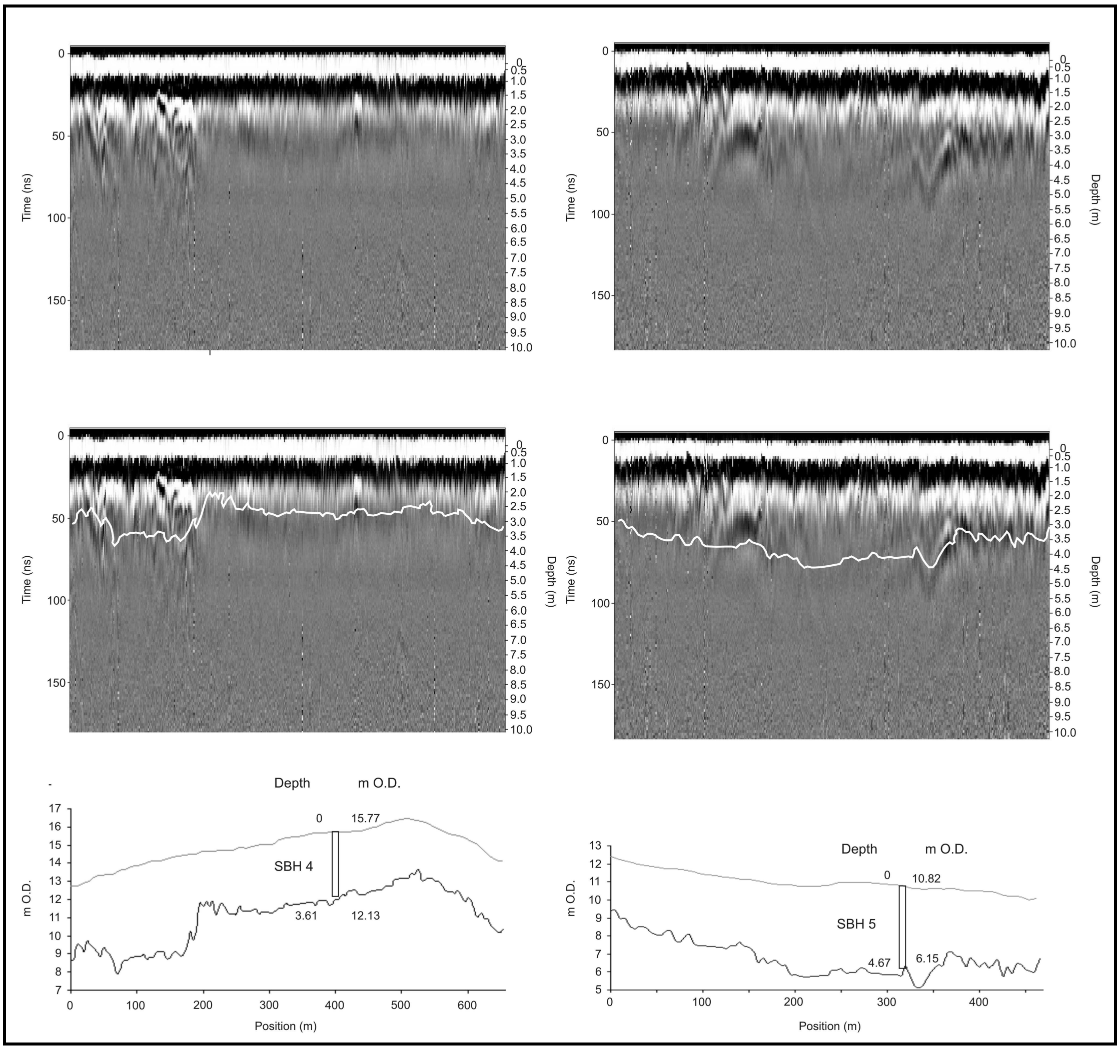


Figure 4.23. Northeast to southwest GPR trace outputs of Chilling Copse Lines D and E (top) with interpretation of bedrock contact (middle). Bottom image is a profile of the GPR transect with synthetic boreholes CHC SBH 4 and 5 locations and heights shown.

Table 4.12. Synthetic borehole data generated from GPR transects in the Warsash area. The current terrace attributions of Edwards and Freshney (1987) and Westaway *et al*. (2006) are shown.

Reference	Easting	Northing	Ground level (m O.D.)	Terrace thickness (m)	Bedrock height (m O.D.)	Terrace E. & F. (1987)	Terrace W. *et al*. (2006)
CHC SBH 1	451935	104101	12.14	4.40	7.74	Terrace 3	Mottisfont (T3)
CHC SBH 2	451900	104145	15.04	3.95	11.09	Terrace 3	Mottisfont (T3)
CHC SBH 3	451880	104167	15.55	3.60	11.95	Terrace 3	Mottisfont (T3)
CHC SBH 4	451761	104210	15.74	3.61	12.13	Terrace 3	Mottisfont (T3)
CHC SBH 5	451546	103832	10.82	4.67	6.15	Terrace 2	Hamble (T2)
CHC SBH 6	451569	103825	10.50	4.54	5.96	Terrace 2	Hamble (T2)
CHC SBH 7	451500	103840	10.90	4.44	6.46	Terrace 2	Hamble (T2)
CHC SBH 8	451485	103844	10.92	4.60	6.32	Terrace 2	Hamble (T2)

4.5 The borehole record of the Test Valley region

The available borehole archive from terraces attributed to the Test River in the Test Valley region (Edwards and Freshney 1987; Booth 2002; Harding *et al.* 2012; Bates *et al.* 2004, 2007; Bates and Briant 2009) was assessed for inclusion in this study as set out in Chapter 3 (Methods). Boreholes that contained sands and gravels of likely fluvial origin and provided location, ground level and bedrock contact data were included. The resulting dataset consists of 280 records (Table 4.13, Table 4.18, at end of chapter) that have been used to generate long profile projections as set out in sections 4.6 and 4.7 below. The borehole dataset (Figure 4.24) is not evenly distributed for all terrace levels, with the frequency of boreholes generally declining up the sequence with Terraces 5, 7, 8, 10 and 11 poorly represented. This is due to the higher terraces being largely located in less urbanised areas, where fewer development works have resulted in a smaller borehole archive, as well as being more fragmentary and less spatially extensive.

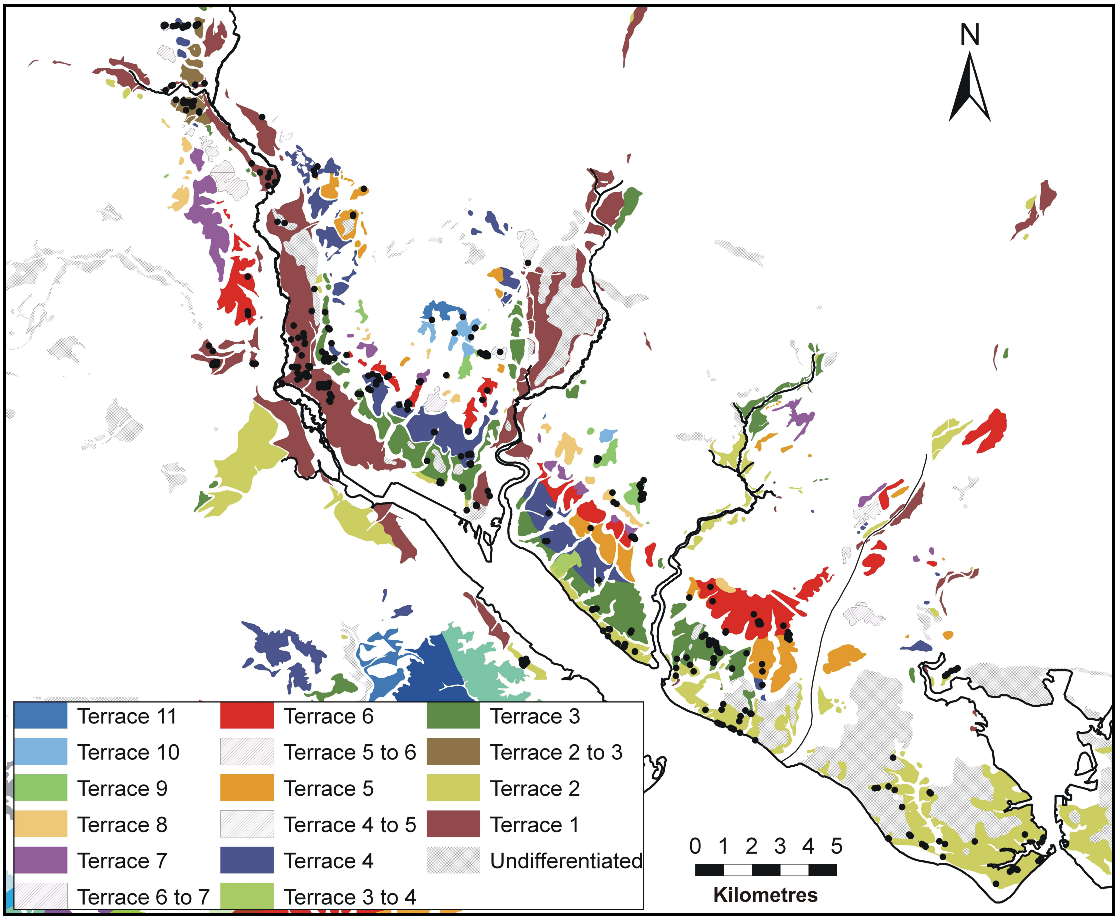


Figure 4.24. Location map of boreholes in the terraces of the Test region (mapping scheme of Edwards and Freshney 1987, Booth 2002).

Table 4.13. Distribution of the 280 borehole records from the Test Valley region used in the study. Terrace attributions as mapped by the BGS (Edwards and Freshney 1987; Booth 2002) and Westaway *et al*. (2006).

Scheme	T1	T2	T2/3	T 3	T4	T5	T6	T6/7	T7	T8	T9	T10	T11	T12	Total
BGS	64	65	1	40	35	9	28	1	5	4	22	4	2	-	280
W. *et al*.	62	64	-	18	54	16	28	1	5	12	-	-	15	5	280

4.6 The terraces of the Test Valley region: the Edwards and Freshney (1987) and Harding *et al.* (2012) schemes compared

This section will describe and define the extent of the terraces deposited by the River Test in the Test Valley region. Terraces are presented in the nomenclature of the BGS (Edwards and Freshney 1987; Booth 2002) and Harding *et al.* (2012) with alternative attribution by PASHCC (Bates *et al*. 2004, 2007; Bates and Briant 2009; Briant *et al*. 2012) highlighted as necessary. The 280 borehole logs collected during this study have been assigned to the appropriate terrace level as defined by these schemes. Fieldwork conducted in the Test Valley Region has produced a significant additional dataset for a number of key terraces in the study area, consisting of bedrock contact, ground level and (excluding GPR data) gravel thickness. The non-borehole dataset for the Test Valley region consists of 30 synthetic borehole logs generated by this study (Table 4.15, at end of chapter), 30 PASHCC (Bates *et al*. 2004, 2007; Bates and Briant 2009) section logs (Table 4.16, at end of chapter) and 11 Bridgland and Harding (1987; Harding *et al*. 2012) section logs (Table 4.17, at end of chapter), which have similarly been attributed to a terrace according to the two schemes. The resulting long profile projections (Figure 4.25) reveal considerable variation in the altitudinal range of a number of terraces as currently classified in the Test Valley when additional borehole and fieldwork data are included in projections. Minor adjustments to the higher BGS terrace attributions (largely Terraces 7 to 11) are made by Westaway *et al.* (2006) as discussed below. Correlation issues between the two schemes relate predominantly to the downstream projection of the terraces mapped in the Winchester Sheet (particularly around Dunbridge, discussed above) with those in the Southampton Sheet (around Warsash). The upstream dataset is limited predominantly to fieldwork carried out during this study at Dunbridge and a group of PASHCC (Bates *et al*. 2004, 2007; Bates and Briant 2009) sections to the north. Correlation from this limited dataset will be dealt with in Chapter 4.7, after the more substantial downstream terrace record has been assessed.

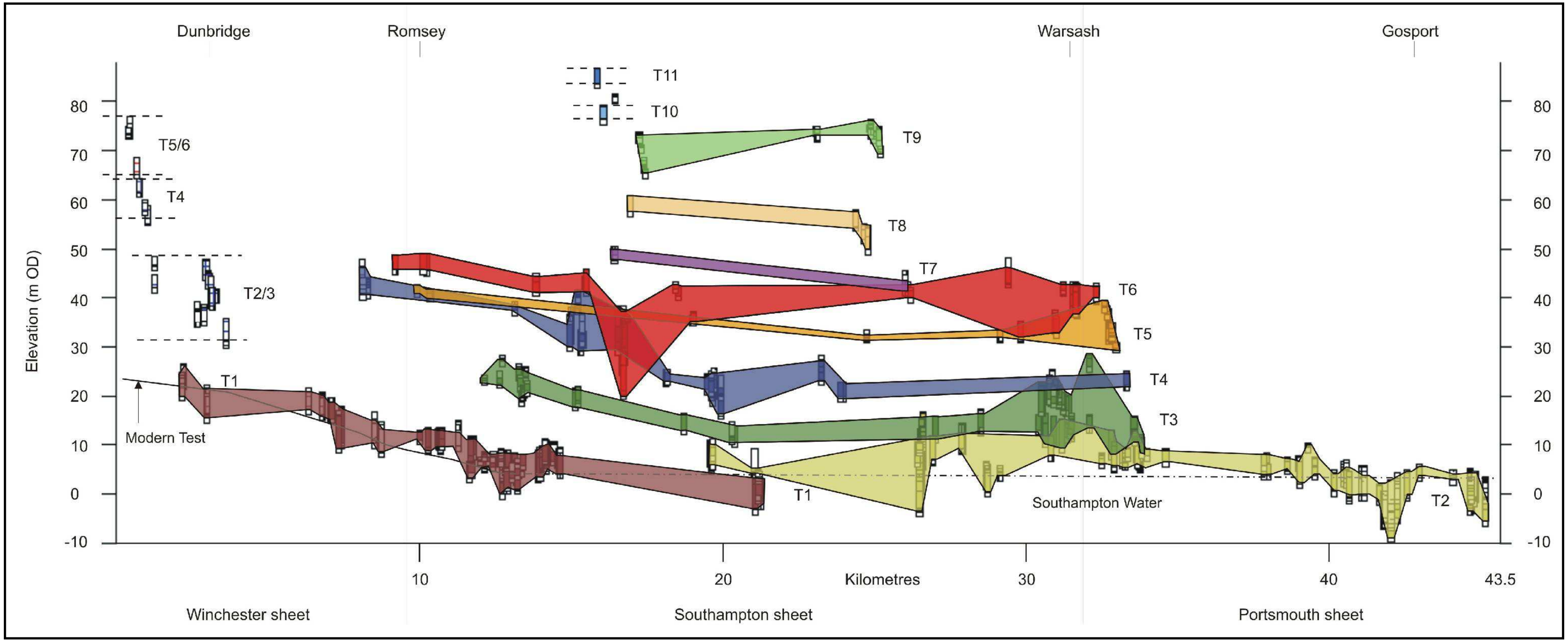


Figure 4.25. The terrace stratigraphy of the Test Valley using borehole and fieldwork data collated during this study. Mapping nomenclature is that of Edwards and Freshney (1987) (Southampton sheet) and Booth (2002) (Winchester sheet). Alternative terrace attributions of the Westaway *et al.* (2006) scheme around Warsash and in the higher Test terraces are set out in the text. Profile projected along N135°E with distance measured from zero at SU 31595 29000.

Terrace 1

Terrace 1 in the Test sequence survives as an extensive, near-continuous spread of fluvial deposits from north of Dunbridge to Southampton Water (bridging the Winchester and Southampton BGS sheets). At the upstream end of the profile (Figure 4.26) a single borehole just north of Dunbridge is mapped as Terrace 1. SU32 NW7 (SU 3268 2632) records ground level at 22.3 m O.D., with bedrock at 16.2 m O.D. Three boreholes of similar elevation (between 22.3 m to 22.45 m O.D.) appear to be associated with the confluence with the tributary River Dun. A spread of Terrace 1 then extends downstream from north of Romsey. Here boreholes SU32 SW3, 4 and 8 (around SU 3460 2330) record ground level from 21.7 to 19.8 m O.D. with bedrock between 17.2 to 15.7 m O.D. In a group of boreholes at Nursling, at the southern extent of this deposit of Terrace 1, bedrock height averages around 5 m O.D., although three boreholes record bedrock at around 1 m. Up to 5 m of gravel is recorded, averaging around 3.4 m in thickness with ground level between 9 m and 10.9 m O.D. Downstream at the confluence with the River Itchen, Terrace 1 is seen in five boreholes with ground level between 3.1 m and 5.2 m O.D. and bedrock at an average elevation of -1.3 m O.D. Terrace 1 is not present on-shore south of Southampton, with current BGS mapping (Edwards and Freshney 1987) showing that it now sits below Southampton Water. Extending the gradient of Terrace 1 south from around the Itchen suggests a possible correlation with a number of boreholes around Gosport (recorded as Terrace 2), as discussed below.

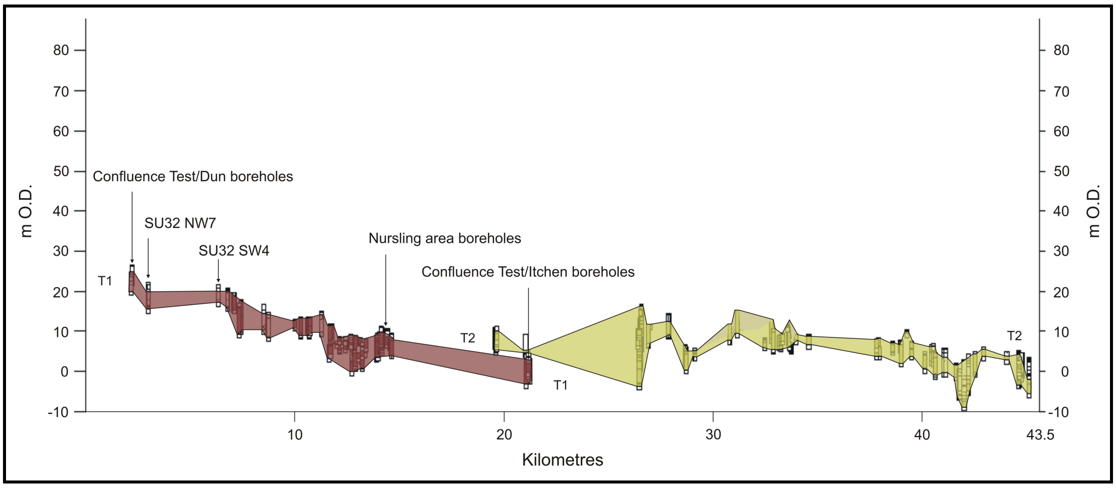


Figure 4.26. The long profile projection and distribution of data points in Terrace 1 of Edwards and Freshney (1987)/Booth (2002) and Broadlands Farm of Westaway *et al*. (2006). Terrace 2 included for comparison. Profile projected along N135°E with distance measured from zero at SU 31595 29000.

Terrace 2

Terrace 2 (Figure 4.27) is the most extensive deposit although it has restricted distribution north of Southampton. A near-continuous spread of fluvial deposits remain from north of the River Itchen to the modern coast at Gosport, dissected by the Itchen and River Hamble. At Southampton, just northwest of the Itchen, Terrace 2 is recorded in a closely-spaced group of seven boreholes (SU41 SW431 to 435, 439 and 440) centred on SU 4100 1226. Ground level is at around 10.9 m O.D., with between 2.3 and 4.8 m of gravels overlying bedrock ranging between 5.1 m and 7.7 m O.D. Downstream on the west bank of Southampton Water a group of 12 closely-spaced boreholes at Fawley (SU40NW68, 69 to 72, 77, 80, 83, 86, 87, 89 & 91) (around SU40 4390 0590) record ground level between 16.6 m O.D. and 6.4 m O.D. Bedrock level is between 13.75 m O.D. and -3.7 m O.D. The height differential in the elevation of ground level and bedrock contact recorded in the available logs appears considerable for a single terrace level (see Figure 4.34 below). On the opposite bank a group of six boreholes near the Test/Hamble confluence (SU40 NE15 to 19 and 91) (around SU4 4750 0645) record ground level between 4.9 m and 5.8 m O.D., with ground level between 0.5 m and 3.7 m O.D. Finally around Gosport, another group of boreholes indicate a wide vertical range. Bedrock at the downstream end of Terrace 2 at Gosport has a mean elevation of around -0.7 m O.D. overlain by around 3 m of gravels. A cluster of six boreholes record bedrock between -5 m and -9 m however (see Figure 4.34 below).

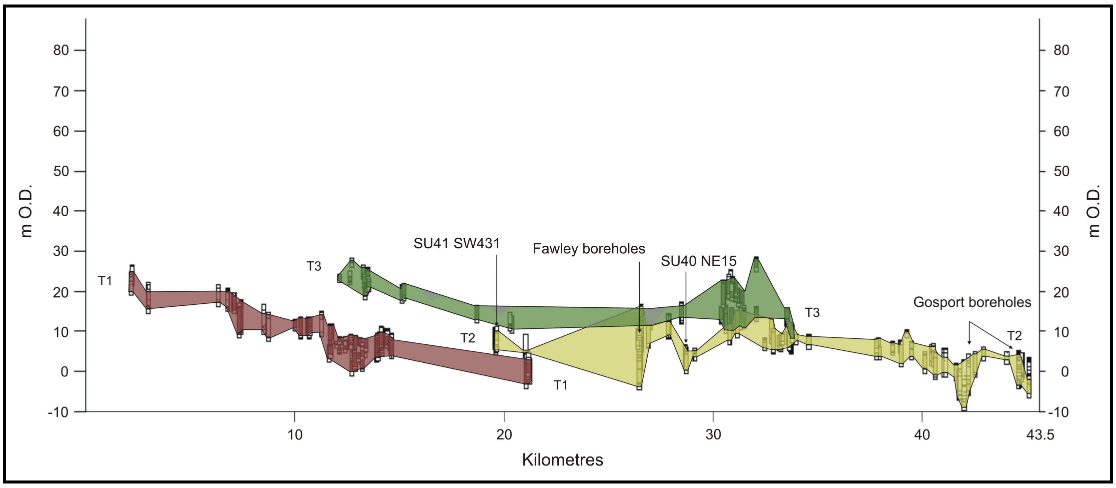


Figure 4.27. The long profile projection and distribution of data points in Terrace 2 of Edwards and Freshney (1987)/Booth (2002) and Hamble of Westaway *et al*. (2006). Terraces 1 and 3 included for comparison. Profile projected along N135°E with distance measured from zero at SU 31595 29000.

Terrace 3

Terrace 3 (Figure 4.28) is not present north of Romsey or south of Warsash. Upstream at Romsey boreholes SU31 NE 32, 208 and 209 (around SU3704 1770) record ground level between 24.1 m to 28.1 m O.D. and bedrock between 23.1 m to 27.1 m. A nearby group of seven boreholes record comparable elevations. Downstream the terrace is sparsely represented until the Warsash area, where the majority of Terrace 3 boreholes are located. Around Warsash there is an increased vertical variation in bedrock and ground level elevations compared to elsewhere in the terrace, with overlap with Terrace 2 and Terrace 4 in the area (see Figure 4.37 below). Sections at Warsash Common (WAC10) and Hamble Park (HAP10) are mapped as Terrace 3, with bedrock at 11.5 m O.D. This terrace is altitudinally distinct from Terrace 2 at Solent Breezes (SOB10) around 2 km to the south (bedrock at around 7 m). A number of borehole records in Terrace 3 to the north of Warsash, however, record bedrock in the range of 15.8 m to 25.8 m O.D. Harding *et al*. (2012) correlate their Mottisfont/ Lower Warsash terrace with Terrace 3 downstream at Warsash, also revising the extent of the terrace north of Warsash (Figure 4.28).

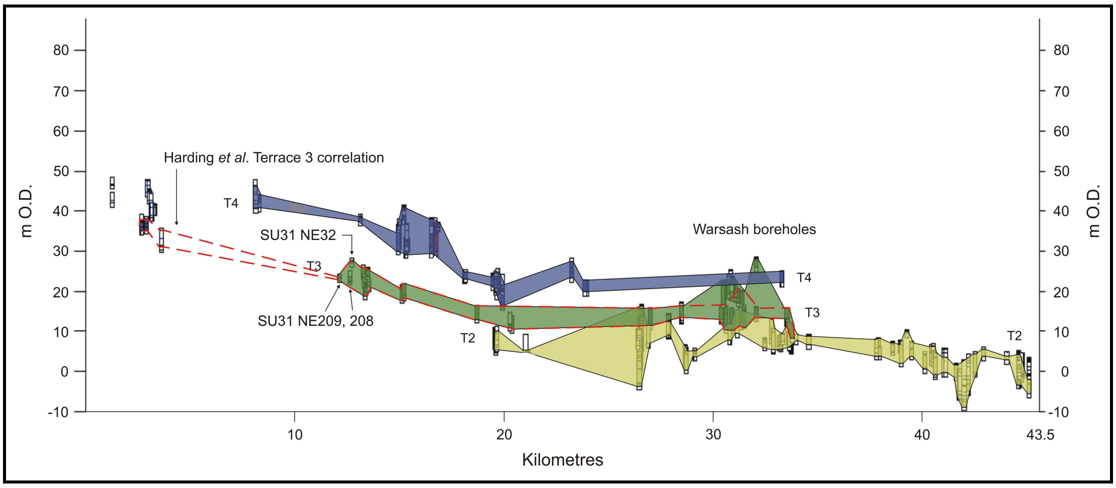


Figure 4.28. The long profile projection and distribution of data points in Terrace 3 of Edwards and Freshney (1987) and Mottisfont/Lower Warsash of Westaway *et al.* (2006)/ Harding *et al.* (2012). Terraces 2 and 4 included for comparison. Profile projected along N135°E with distance measured from zero at SU 31595 29000.

Terrace 4

Terrace 4 (Figure 4.29) has a more restricted distribution, being concentrated north and south of Southampton with only a single small patch downstream of the Hamble

River mapped by the BGS (Edwards and Freshney 1987). Harding *et al*. (2012) recognise their Belbin/Upper Warsash terrace further downstream from Netley to Warsash, correlative with the higher Dunbridge terrace. PASHCC (Bates *et al*. 2004, 2007; Bates and Briant 2009; Briant *et al*. 2012) correlate Terrace 4 of the Southampton BGS sheet with the lower Dunbridge terrace as shown in Figure 4.29. Upstream at Abbotswood ground level is recorded at 44 m O.D. and bedrock contact at 40.9 m O.D. (borehole SU32 SE97 (SU3657 2309)). Downstream PASCHH test-pit 2 at Hook (Bates *et al*. 2004, 2007) records ground level at 25 m O.D. and bedrock at 22.3 m O.D. The terrace shows great variety in bedrock height and gravel thickness along its reach, suggesting that more than one terrace may be presently recorded as Terrace 4 in the region as discussed in the next section.

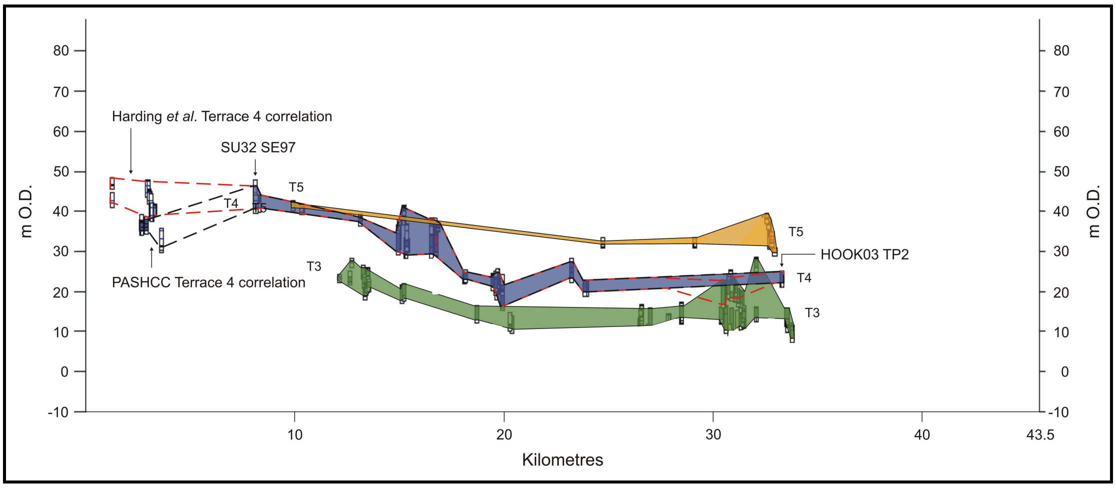


Figure 4.29. The long profile projection and distribution of data points in Terrace 4 of Edwards and Freshney (1987)/ Booth (2002) and Belbin/Upper Warsash of Westaway *et al*. (2006)/ Harding *et al.* (2012). Terraces 3 and 5 included for comparison. Profile projected along N135°E with distance measured from zero at SU 31595 29000.

Terrace 5

Boreholes in Terrace 5 (Figure 4.30) are limited in number and distribution, with the majority of available records at the downstream end of the reach. The terrace is represented between Romsey to the north and Warsash to the south. Upstream ground level in borehole SU32 SE17 and PASHCC (Bates *et al*. 2004, 2007) test-pits WARF03 TP1 & 2 ranges from 42.7 m O.D. and 41.8 m O.D. and bedrock 41 m O.D. to 40 m O.D. Downstream at Titchfield Park a closely spaced group of boreholes record ground level between 39.4 m and 34.9 m O.D. and bedrock from 38 m to 31.5 m O.D., showing significant variation in elevation (see Figure 4.34 below). In nearby PASHCC (Bates *et al*. 2004, 2007) test-pits HOOKF03 TP1 & 3 ground level is at 33.1 m and 30.8 m O.D. and bedrock is at 31.7 m and 29.8 m O.D. respectively. The PASHCC project (Bates *et al*. 2004, 2007; Bates and Briant 2009; Briant *et al*. 2012) correlates Terrace 5 with the higher terrace at Dunbridge as shown in Figure 4.30.

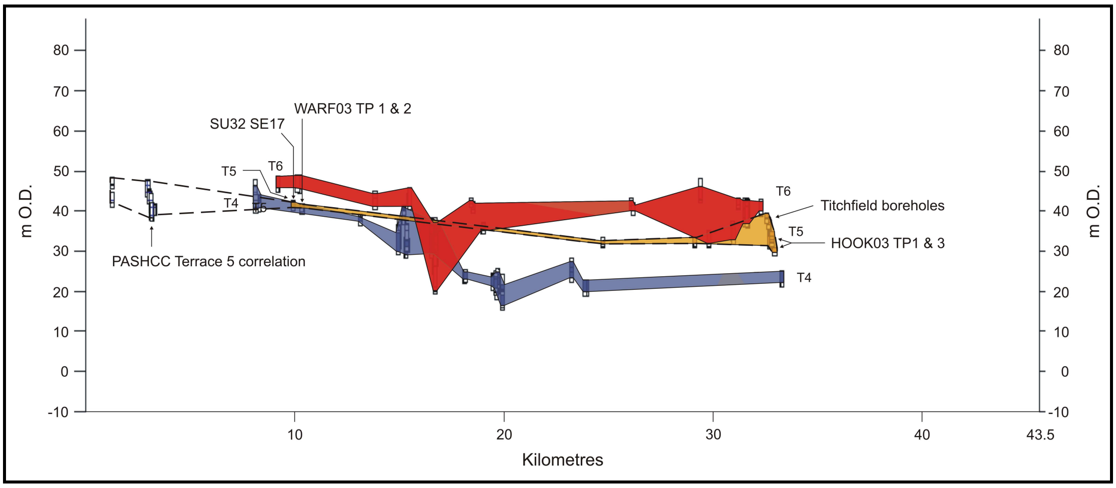


Figure 4.30. The long profile projection and distribution of data points in Terrace 5 of Edwards and Freshney (1987) and Ganger Wood/ Mallards Farm of Westaway *et al.* (2006). Terraces 4 and 6 included for comparison. Profile projected along N135°E with distance measured from zero at SU 31595 29000.

Terrace 6

Terrace 6 (Figure 4.31) is recorded with ground level between 48.77 m upstream (Pauncefoot Hill, north of Romsey) and 42.9 m O.D. downstream (Titchfield, north of Warsash), with the corresponding bedrock level at 45.75 m and 39.7 m O.D. Gravel thickness is up to 6.1 m, and averages around 3.8 m. Terrace 6 appears to have a number of correlation errors in the dataset, with four boreholes near the bluff of the terrace at Southampton General Hospital recording bedrock between 20 m and 28 m O.D. Further downstream in the area around Locks Heath ground level and bedrock height show variation in recorded elevation of between 10 to 12 m over ~1.5 km.

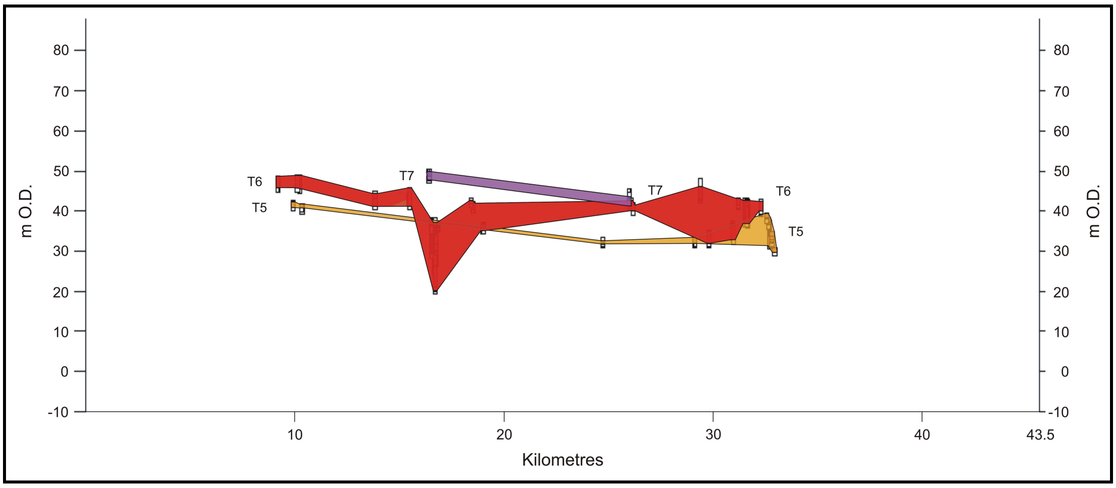


Figure 4.31. The long profile projection and distribution of data points in Terrace 6 of Edwards and Freshney (1987) and Nursling/ Burseldon of Westaway *et al.* (2006). Terraces 5 and 7 included for comparison. Profile projected along N135°E with distance measured from zero at SU 31595 29000.

Terraces 7 to 11

Terraces 7 to 11 (Figure 4.32) have limited outcrops to the north and north east of Southampton, with a more extensive spread of Terrace 7 west of Romsey. The terraces are also poorly represented in the borehole archive. The only available data upstream in BGS sheet 299 (Winchester) are five PASHCC logs. It is not practical to calculate terrace gradients based on such limited distribution but upstream correlation into BGS sheet 299 based on altitude will be suggested in the next section.

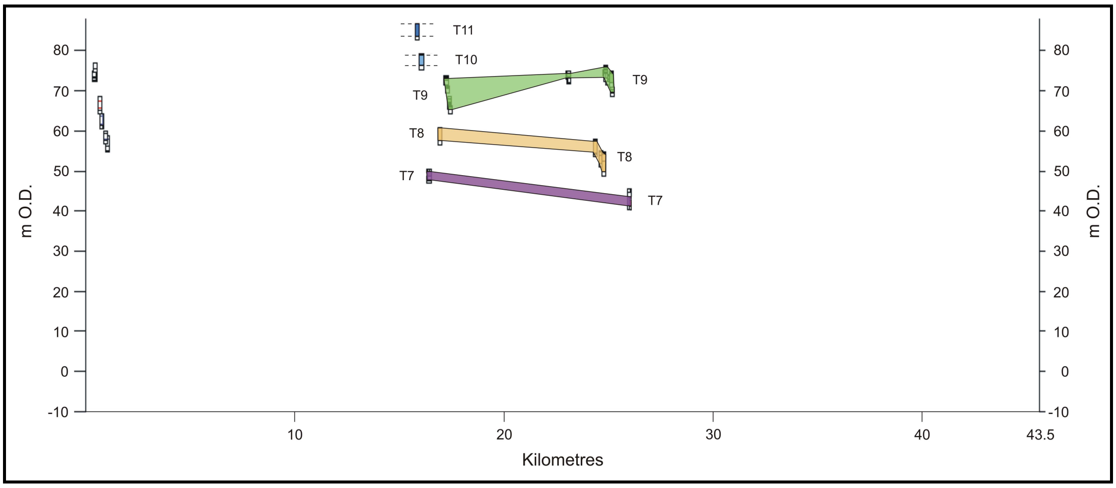


Figure 4.32. The long profile projection and distribution of data points in Terraces 7 to 11 of Edwards and Freshney (1987) and the Bitterne to Chilworth terraces of Westaway *et al.* (2006). Profile projected along N135°E with distance measured from zero at SU 31595 29000.

4.7 Reassessing the terrace stratigraphy of the Test Valley region

Comparison of the BGS (Edwards and Freshney 1987; Booth 2002) and Harding *et al.* (2012) schemes indicate a number of issues with the current stratigraphy of the Test terraces. The River Test terrace sequence, when projected using the expanded dataset of borehole records and fieldwork data collected here, loses distinction in its downstream gradients which frequently overlap. The terrace stratigraphy at key localities in the Warsash area also requires further investigation to clarify the sequence and provide a basis for upstream correlation. Therefore a reassessment of the terrace stratigraphy of the Test Valley was undertaken as described in Chapter 3.6 using the additional dataset produced by this study. In order to tackle the mapping issues in the region (Chapter 2.4.2 and sections 4.2, 4.3 and 4.4 above), areas of agreed attribution of terrace extent were used to provide a foundation for re-interpretation.

The following section will describe the location and data of borehole records that have been reassigned in this study and outline the reasoning behind those changes made. Figure 4.33 shows the location of reassigned logs and the corresponding terrace mapping revisions that resulted. Data records that have been reassigned are numbered as in Table 4.14 and discussed in the relevant sections below. A revised long profile projection of the terrace stratigraphies of the River Test is presented in Figure 4.34.

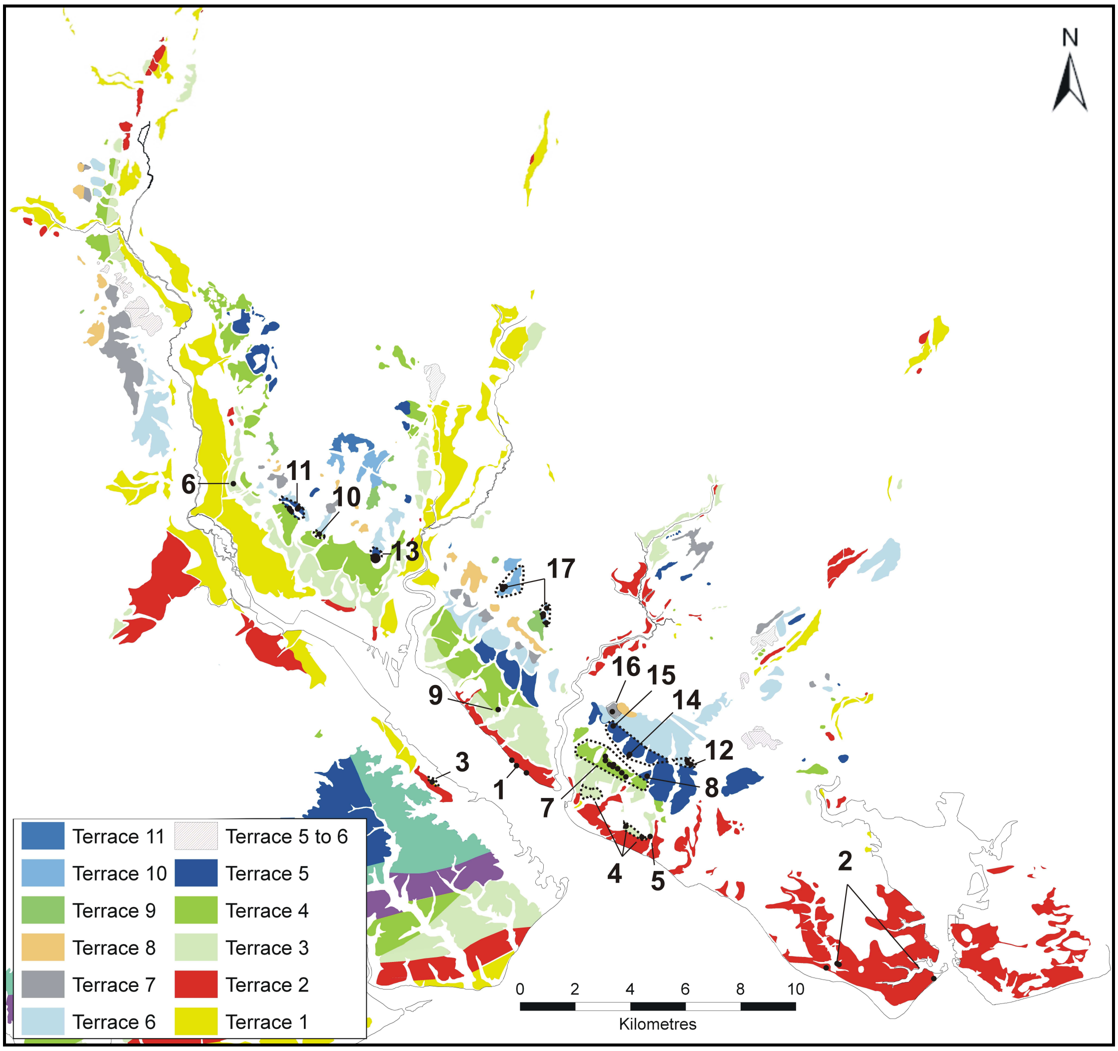


Figure 4.33. Mapping of the terrace stratigraphy of the River Test in the Test Valley region as reassigned by this study (cf. Figure 4.1). Numbers show locations of borehole records and fieldwork data reassigned as in Table 4.14 and discussed in the appropriate sections below. Dashed lines show extent of mapping alterations.

Table 4.14. Adjustments made to terrace correlations and borehole data points in the Test Valley region record. Columns 3, 4 and 5 show the mapping schemes of Edwards and Freshney (1987)/Booth (2002), Westaway *et al.* (2006)/Harding *et al*. (2012) and PASHCC (Bates *et al*. 2004, 2007; Bates and Briant 2009; Briant *et al*. 2012) respectively. Columns 6 and 7 show the revised attribution and rationale.

			Previous mapping			
Fig. Note	Reference	BGS	Westaway et al.	PASHCC	Revised terrace	Rationale
1	SU40NE 145, 165 & 167	Terrace 2	Hamble	Terrace 2	Excluded	Altitudinally low for Terrace 2, probably located on eroded terrace edge
2	SZ59NE4 & 34, P917, P921, P373	Terrace 2	Hamble	Terrace 2	?Terrace 1	Section shows two gravel deposits separated by peats or clays
3	SU40NW86 & 87	Terrace 2	Hamble	Terrace 2	Terrace 1	Altitudinally more consistent with Terrace 1 in the locality
4	SU50SW21 & 26; CHRD SBH3	Terrace 2	Hamble	Terrace 2	Terrace 3	Altitudinally more consistent with Terrace 3 in the locality
5	SU50SW16	Terrace 3	Mottisfont	Terrace 3	Terrace 2	Altitudinally more consistent with Terrace 2 in the locality
6	SU31NE52	Terrace 3	Mottisfont	Terrace 3	Excluded	Ground level low compared to borehole and topography data from locality
7	North Warsash boreholes (see text)	Terrace 3	Belbin/ Upper Warsash	Terrace 3	Terrace 4	Long profile shows existence of two terrace levels at Warsash; mapped as Terrace 3 by the BGS
8	SU50NW214	Terrace 3	Belbin/ Upper Warsash	Terrace 3	Terrace 5	Altitudinally more consistent with Terrace 5 in the locality
9	SU40NE80	Terrace 4	Terrace ?Belbin	Terrace 4	Excluded	Located in the valley of a tributary stream
10	SU31SE263, 264, 346, 347, 348 and 349	Terrace 6	Nursling/ Burseldon	Terrace 6	Terrace 4	Altitudinally more consistent with Terrace 4 in the locality
11	SU31NE371D, E and G	Terrace 4	Belbin/ Upper Warsash	Terrace 4	Terrace 5	Altitudinally more consistent with Terrace 5 in the locality
12	SU50NW467, 469, 470 and 471	Terrace 5	Mallards Moor	Terrace 5	Terrace 6	Altitudinally more consistent with Terrace 6 in the locality
13	SU41SW476 & 477	Terrace 6	Nursling/ Burseldon	Terrace 6	Terrace 5	Altitudinally more consistent with Terrace 5 in the locality.
14	SU50NW177 & 178	Terrace 6	Nursling/ Burseldon	Terrace 6	Terrace 5	Altitudinally more consistent with Terrace 5 in the locality; could be edge of terrace
15	SU50NW186	Terrace 6	Nursling/ Burseldon	Terrace 6	Terrace 5	Altitudinally more consistent with Terrace 5 in the locality
16	SU50NW353	Terrace 6	Nursling/ Burseldon	Terrace 6	Terrace 7	Altitudinally more consistent with Terrace 7 in the locality.
17	SU41SE301, 303, 306, 317, 322, 324, 368, 369 and 371	Terrace 9	Netley Hill	Terrace 9	Terrace 10	Altitudinally more consistent with Terrace 10

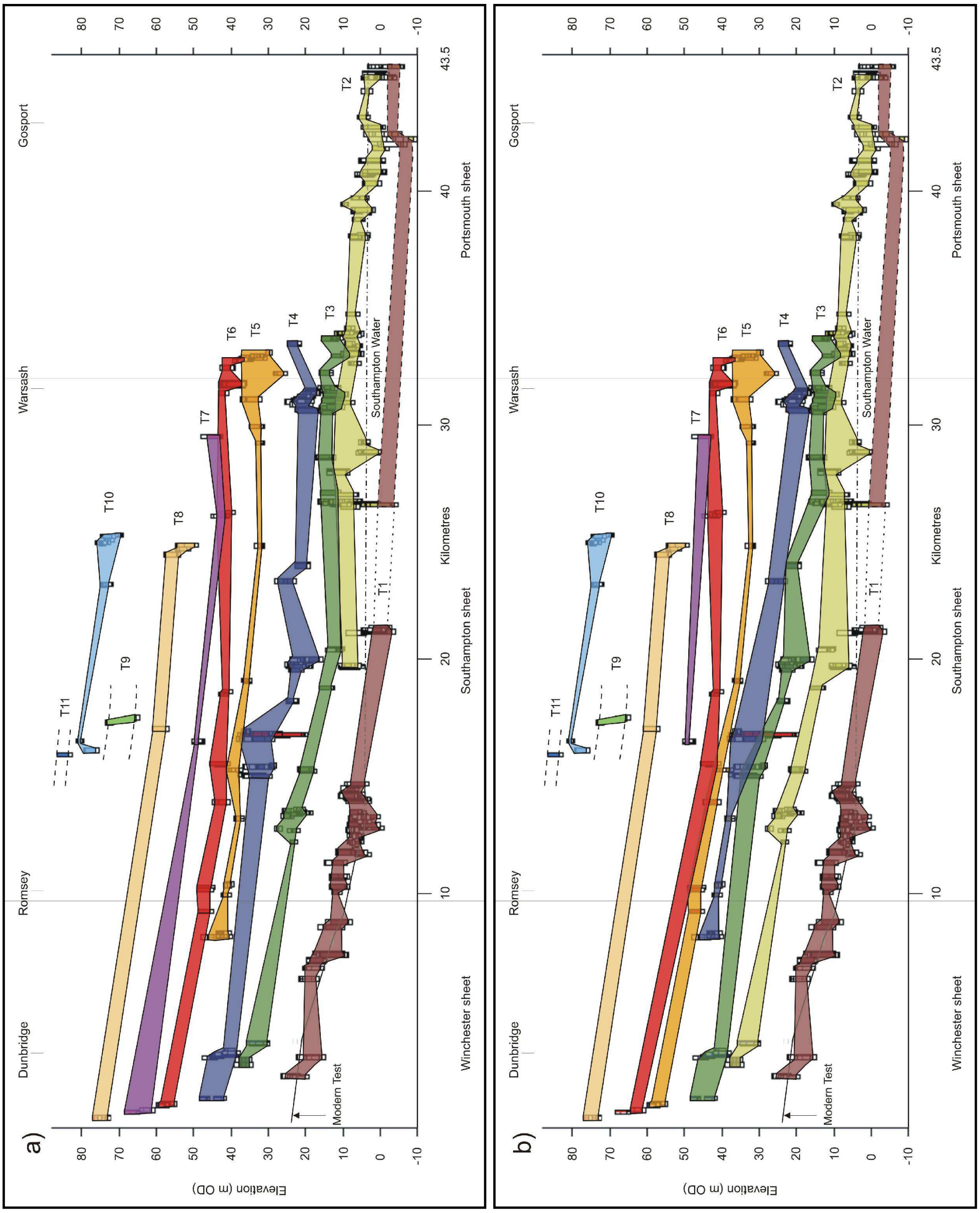


Figure 4.34. The terrace stratigraphy of the River Test in the Test Valley region as assigned by this study. Suggested upstream correlation between deposits in BGS map sheets 315 (Southampton) and 299 (Winchester) are shown in alternative schemes as discussed in the text: a) the shallower correlation into sheet 299 preferred here; b) an alternative steeper correlation into sheet 299. Profile projected along N135°E with distance measured from zero at SU 31595 29000.

As previously noted there are two key issues to be resolved in assessing the Test Valley fluvial sequence. The first is to correlate the mapping schemes of the Winchester BGS sheet (299) and the Southampton BGS sheet (315), and the second is to establish the attribution of the often fragmentary terrace bodies in the region. Test Terrace 1 consists of extensive fluvial landforms and sediments that form a coherent, identifiable terrace body. The gradient change that is seen in Terrace 1 around Romsey complicates correlation between the Southampton and Winchester BGS sheets. Figure 4.34a and b shows alternative upstream correlations which are assessed in the text below. The shallower correlations proposed by PASHCC and those of Harding *et al*. (2006) are discussed in the appropriate terrace sections below. Terrace 2 also survives in extensive spreads of fluvial gravels at the downstream end of the course of the Test, and projects upstream at a higher/older level than Terrace 1. Terraces 1 and 2 form the foundation for constructing the remainder of the Test terrace sequence.

Borehole records located on terraces laid down by tributary rivers (principally the Rivers Itchen and Hamble) were omitted from the revised long profile projection for the Test valley. The majority were to be found upstream from the confluence of the Test and the tributary, and could not easily be related to the main Test terrace sequence. Borehole records that were located at a confluence point were occasionally included as representative of the shared terrace level that would have existed at that point in the systems development, if they were assessed as being consistent with the terrace in question.

Terrace 1

Few issues were encountered with assessing the borehole records available in Terrace 1, which produced a clear terrace level when plotted as a long profile projection (Figure 4.34). The extensive spread of the terrace in the landscape is easily traceable and continuous over the area where the Terrace 1 gradient increases, which makes it useful as a template for more fragmented terraces. Only records located in the tributary River Itchen, some distance upstream of the confluence, were omitted. The extent of Terrace 1 as assessed by this study therefore remains largely unchanged to previous schemes, with additional recognition of Terrace 1 at Fawley discussed below.

Terrace 2

A number of potential issues were identified in the attribution of deposits within Terrace 2 in current mapping schemes (Table 4.14). Borehole records SU40NE145, 165 and 167 (Figure 4.33, note 1) were excluded due to their location on an eroded terrace edge resulting in erroneously low ground level and bedrock contact heights when compared to other records in the deposit.

The borehole record between Warsash and Gosport appears to indicate possible evidence for two levels of altitudinally/stratigraphically distinct gravel deposits in Terrace 2. Four borehole logs at Gosport (2) and Fawley (2) contain a sequence of bedrock overlain by gravels overlain by peat and organic silts and/or clays overlain by further gravels. A similar sequence is found in the Western Solent, where the lowest two terrace levels (Lepe and Pennington) show lower and upper gravels stacked rather than laterally separated.

At Gosport boreholes SZ59 NE4 and P373 record sequences of 2.4 m of peat and 2.3 m of organic silt/peat/clay silt respectively sandwiched between sandy gravel units (Figure 4.33, note 2). Three further boreholes record bedrock at a similar elevation over O.D. to SZ59 NE4 and P373, containing lower gravels overlain by peat and organic silts (Figure 4.35). Made ground of 4.8 m depth overlies the peat in borehole P921 while the upper deposit in the closely spaced boreholes SZ59 NE34 and P917 consist of ~6.2 m of peat. The stratigraphy and comparatively low ground level in these boreholes possibly indicate a sequence of lower gravels covered by peat deposits with higher gravel deposits subsequently eroded or removed. These boreholes may be indicating the presence of a later Holocene channel cutting into Terrace 2 in the area, although without environmental information it is not possible to attribute the peat/fine-grained or upper gravel deposits.

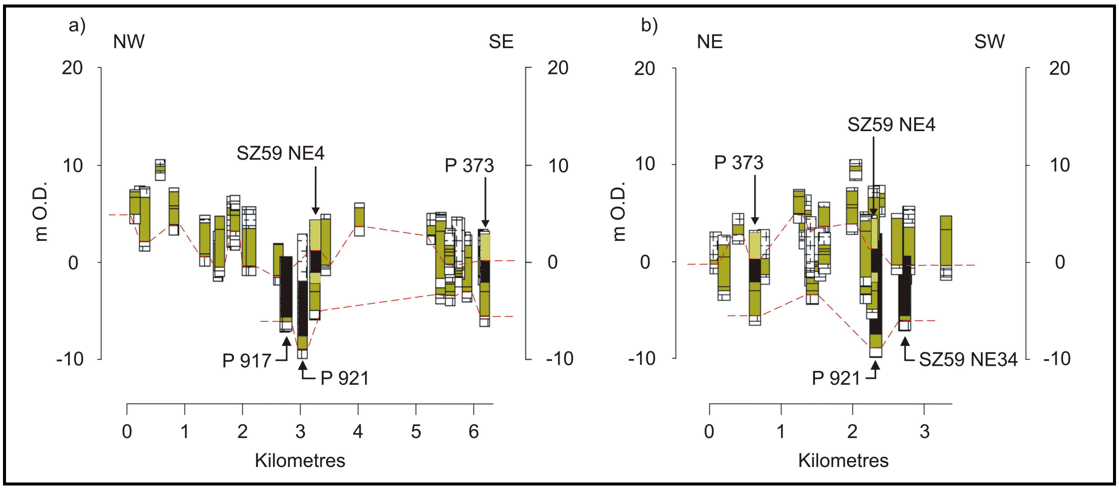


Figure 4.35. Long profile of the borehole record around Gosport. a) As plotted in long profile; b) As plotted in NE – SW cross section. Two distinct gravel units are separated by peat/organic silt deposits in boreholes SZ59 NE4 and P373. Profile a) projected along N135°E with distance measured from zero at SU 57268 03440. Profile b) projected along N220°E with distance measured from zero at SU 60062 01947.

Boreholes SU40NW68, 69, 70, 71, 72, 77, 80, 83, 86, 87, 89 & 91 are located at a level attributed to Terrace 2 at Fawley, on the west bank of Southampton Water (Figure 4.33, note 3). Section long profiles (Figure 4.36) show two possible terrace levels (Test Terrace 2 and Terrace 1) with a degraded surface between them, making it difficult to attribute the location of the bluff or transition between the two levels. Boreholes SU40NW86 and 87 also record a sequence of silty clay/clay and peat deposits separating upper and lower gravels, as seen in boreholes in Terrace 2 around Gosport discussed above. Examining the long profile projection downstream from Terrace 1 (Figure 4.36) appears to support a Terrace 1 attribution for the lower gravels at Fawley on altitudinal grounds, which extends the extent of the terrace in the area. The projection continues to the level of the lower gravel unit at Gosport.

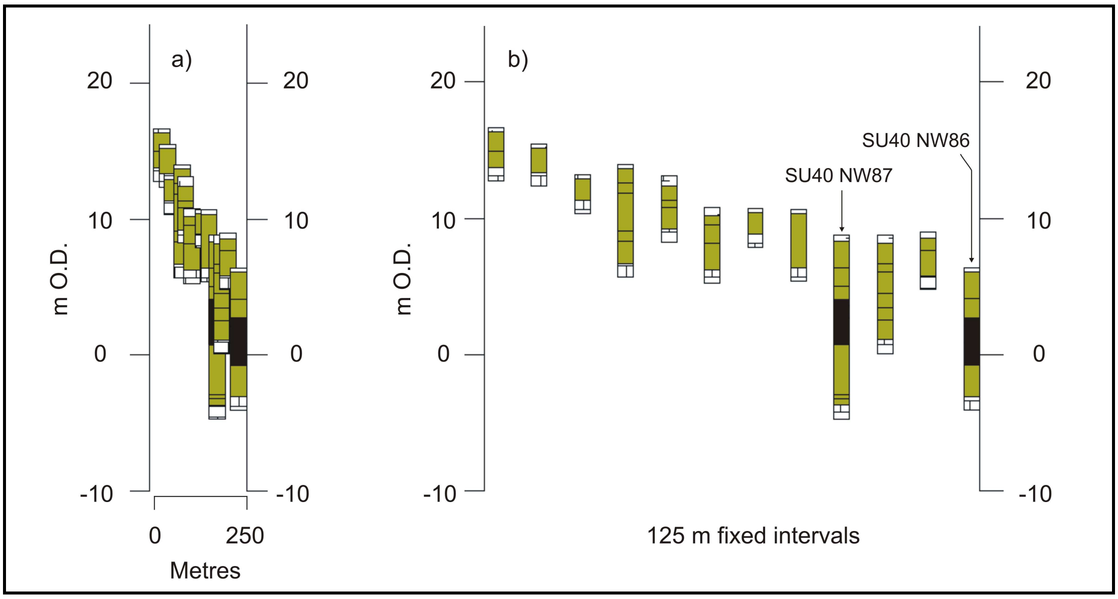


Figure 4.36. Long profiles of the borehole record at Fawley. a) As plotted in section; b) The same section plotted at fixed distances. Two probable terrace levels (Test Terrace 2 and Terrace 1) are indicated, with a degraded surface between them making it difficult to locate the transition between the two. Data is largely consistent with the O.D. height range seen for Terrace 2 and Terrace 1 on the opposite bank of Southampton Water. Profile projected along N45°E with distance measured from zero at SU 43845 05867.

Boreholes SU50SW21 and 26 were reassigned from Terrace 2 to Terrace 3 on altitudinal grounds, as they are close to the mapped boundary between the two terrace levels (Figure 4.33, note 4). Such a change necessitates a slight adjustment to the terrace mapping in the area. Nearby, borehole SU50SW16 (Figure 4.33, note 5) was deemed more altitudinally consistent with Terrace 2 and reassigned accordingly on the same basis as boreholes 21 and 26.

Finally the six boreholes near the Test/Hamble confluence mapped as Terrace 2 project low compared to other Terrace 2 deposits in the area but above the lowest boreholes at Fawley. It is possible that these logs record previously unrecognised Terrace 1 deposits in the area but they may simply reflect an eroded Terrace 2 edge.

The extent of Terrace 2 as assessed by this study remains largely unchanged to previous schemes (Figure 4.33).

Terrace 3

Borehole SU31NE52 (Figure 4.33, note 6) records ground level as 16.36 m but maps onto the 25 m contour in the area. The log was excluded as an erroneous data entry/recording problem. The remaining issues with projecting Terrace 3 were encountered with borehole records and current mapping in the Warsash area.

Extensive fieldwork undertaken during this study around Warsash (Chapter 4.3, above) shows bedrock contact to be around 13.5 m to 11.4 m O.D. (Hatch 2011), as does borehole record SU50NW207. When incorporated into a long profile section of boreholes in the area (Figure 4.37; Hatch 2011) it becomes apparent that more than one terrace level is present in the area mapped as Terrace 3. To the north of Warsash, a series of fourteen boreholes (SU50NW323 to 329, 331 to 336 and 343) mapped as Terrace 3 project onto a previously unrecognised higher terrace level and have accordingly been reassigned to Terrace 4 (Figure 4.33, note 7). This additional terrace level at Warsash was subsequently incorporated into the revision of the Westaway *et al*. scheme (Harding *et al*. 2012).

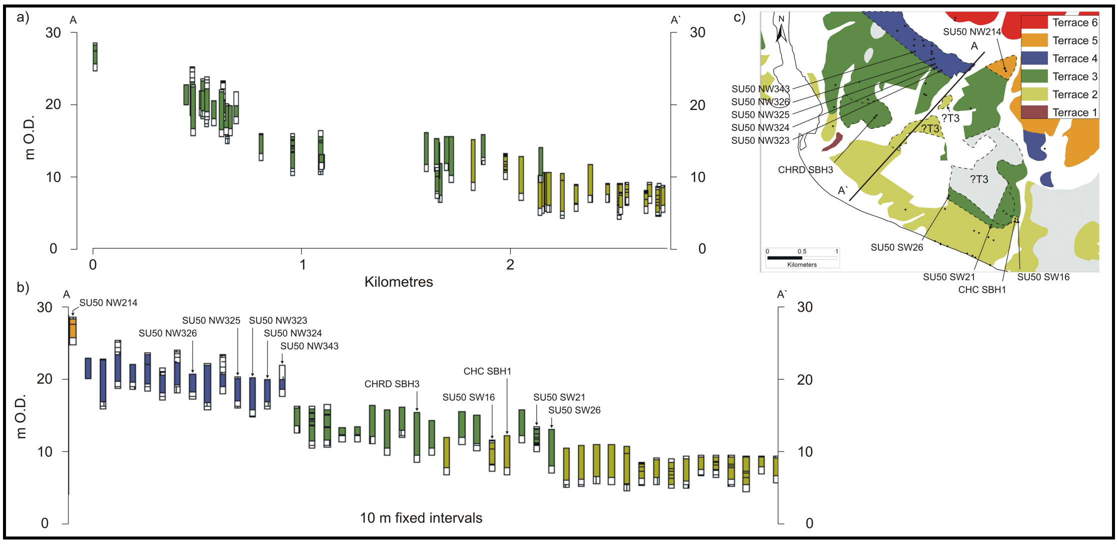


Figure 4.37. Section profiles of the borehole record at Warsash (after Hatch 2011). a) As plotted in section (A – A´) with original terrace attribution; b) The same section plotted at fixed distances, shown with revised attribution; c) location map with the revised terrace attribution of this study. Profile projected along N225°E with distance measured from zero at SU 51423 06626.

A final borehole record located in Terrace 3 required reassessment of its terrace attribution. Borehole SU50NW214 (Figure 4.33, note 8) is one of three logs from the north and east of Warsash that indicate a previously unmapped extension of the spread of Terrace 5 in the area. SU50NW214 projects to a higher level than the Warsash boreholes reassigned to Terrace 4 in the locality, and is interpreted as representing the front edge of the terrace seen in boreholes SU50NW177, 178 and 186 (see below). SU50NW214 is reassigned from Terrace 3 to Terrace 5 to reflect this terrace level, with corresponding adjustments made to the mapped extent of Terrace 5 (Figure 4.33).

The amended extent of Terrace 3 in the Southampton BGS map sheet is recognised in the revised long profile projection (Figure 4.34) from records just north of Romsey to the area southeast of Warsash. The longitudinal extent of the terrace is unchanged, while at its downstream end two additional terrace levels are recognised in deposits previously mapped as Terrace 3. The upstream projection into the Winchester BGS map sheet (299) would appear to be consistent with correlation with the lower terrace level at Dunbridge recorded by GPR (DUN SBH 2 and 3) (Figure 4.34).

Terrace 4

Borehole SU40NE80 (Figure 4.33, note 9) was excluded from Terrace 4 due to its location on the side of a tributary stream valley. Upstream, two groups of boreholes (SU41SW10, 30, 31, 51, 179, 198 and 630 to 633 and SU41SW870 and 871) are interpreted as the front edge of an extensive Terrace 4 deposit. Borehole 632 is excluded from the long profile projection due to the apparent presence of a channel feature or similar, as it records bedrock contact c.4 m lower than the other records in the group.

Boreholes SU31SE265 to 267 (Figure 4.33, note 10) at Southampton General Hospital are attributed to the back edge of Terrace 4. Just to their northeast a group of boreholes (SU31SE263, 264, 346, 347, 348 and 349), mapped as Terrace 6, do not easily fit with that correlation when plotted in a section profile (Figure 4.38). Bedrock altitude is more consistent with Terrace 4 locally and in long profile. The mapping of Terrace 4 here is therefore extended further northeast to incorporate this latter group of boreholes.

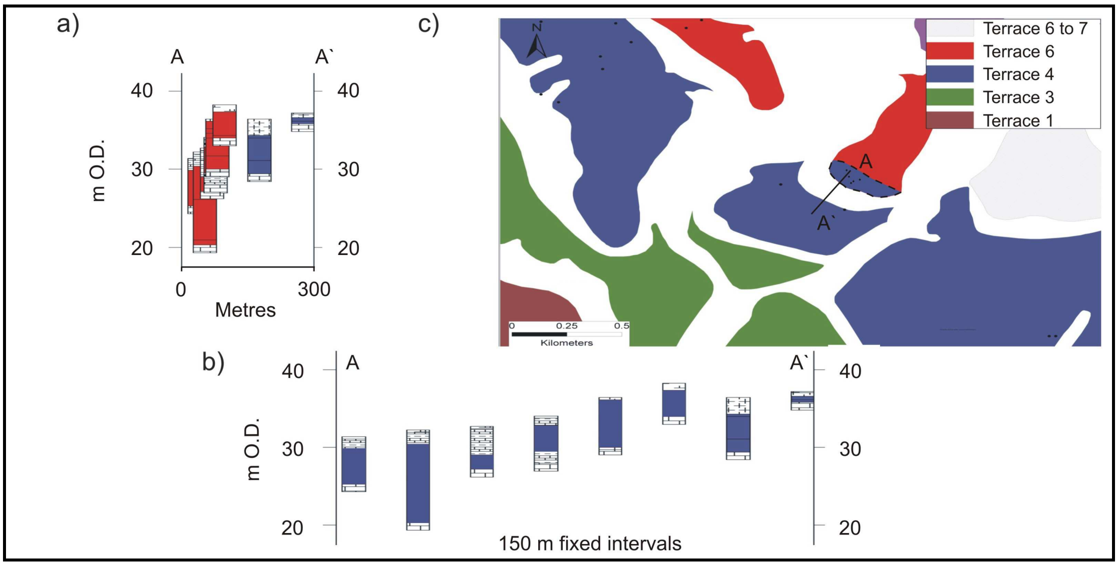


Figure 4.38. Section profiles of the borehole record near Southampton General Hospital a) As plotted in section (A – A´) with original terrace attributions; b) The same section plotted at fixed distances, shown with revised attribution; c) location map with the revised terrace attribution of this study. Profile projected along N225°E with distance measured from zero at SU 39895 15077.

Just upstream, a group of boreholes between Nursling and Lord's Hill (SU31NE172, 189, 190, 193, 194, 341, 343, 371D, 371E and 371G) are mapped as Terrace 4 (Figure 4.33, note 11). An examination of a section long profile (Figure 4.39) reveals two probable terrace levels, with slope deposits in between. Boreholes SU31NE371D, E and G more easily projecting downstream to Terrace 5 and are reassigned accordingly, with the corresponding adjustment made to the terrace mapping in the area.

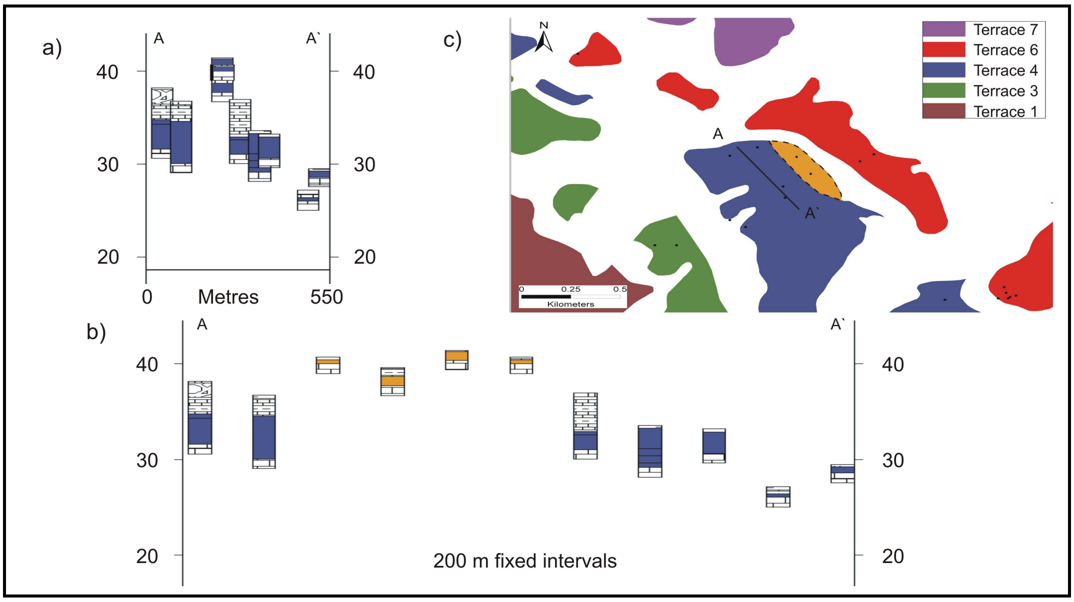


Figure 4.39. Long profiles of the borehole record between Nursling and Lord's Hill. a) As plotted in section (A – A´) with original terrace attributions; b) The same section plotted at fixed distances, shown with revised attribution; c) location map with the revised terrace attribution of this study. Profile projected along N135°E with distance measured from zero at SU 38458 16100.

The amended extent of Terrace 4 in the Southampton BGS map sheet is recognised in the revised long profile projection (Figure 4.34) from records just south of Romsey to the area north and southeast of Warsash, with its longitudinal extent unchanged. At Warsash the terrace is extended northwest to incorporate areas previously mapped as Terrace 3. The upstream projection into the Winchester BGS map sheet (299) would appear to be consistent with correlation with the higher terrace level at Dunbridge recorded by GPR (DUN SBH 1) (Figure 4.34).

Terrace 5

At Titchfield Park, boreholes SU50NW463, 467, 469, 470, 471 and 473, mapped as Terrace 5 (Figure 4.33, note 12), show the presence of two terrace levels when examined in a section long profile (Figure 4.40). Terrace 6 to the immediate north appears to be present in boreholes 467, 469, 470 and 471, and their attribution and the accompanying mapping are adjusted to reflect this interpretation.

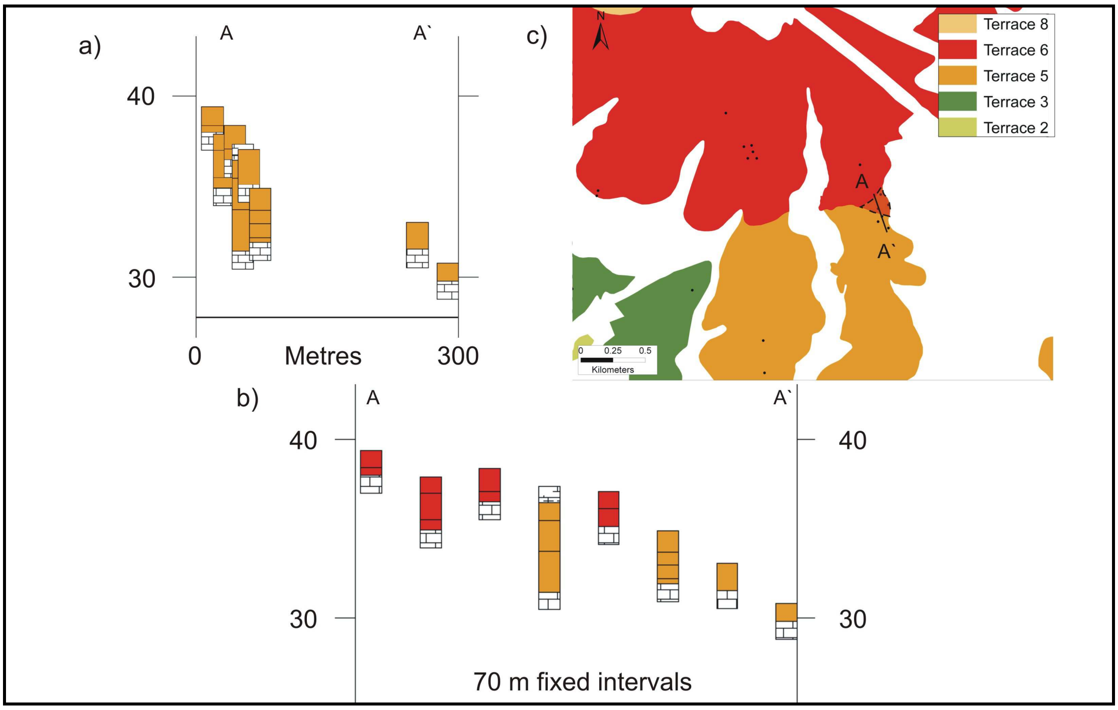


Figure 4.40. Long profiles of the borehole record at Titchfield Park. a) As plotted in section (A – A´) with original terrace attributions; b) The same section plotted at fixed distances, shown with revised attribution; c) location map with the revised terrace attribution of this study. Profile projected along N160°E with distance measured from zero at SU 53214 07025.

Boreholes SU41SW476 and 477, at Westwood Park, are mapped the southern end of an extensive, discontinuous spread of Terrace 6 (Figure 4.33, note 13). Ground level and bedrock contact data are more consistent however with Terrace 5 at that part of the long profile projection. Their attribution and the accompanying mapping of the area are therefore adjusted to reflect this interpretation.

The amended extent of Terrace 5 in the Southampton BGS map sheet is recognised in the revised long profile projection (Figure 4.34) from records around Nursling and Westwood Park to the area east of Warsash, with its reach extended upstream. The terrace is extended between Terrace 4 and Terrace 6 north of Warsash. The upstream projection into the Winchester BGS map sheet would appear to incorporate boreholes SU32SE96 to 98 at Abbotswood, mapped as Terrace 4 but immediately north of a spread of Terrace 5. These three boreholes are reassigned to Terrace 5 here (Figure 4.33). Terrace 5 would then appear to project further upstream above the higher terrace level at Dunbridge (interpreted here as Terrace 4) but below the next highest terrace level recorded at Great Copse to the north. It therefore appears to be absent from the northern extent of the Test long profile projection (Figure 4.34).

Terrace 6

In this study's revision of Terrace 6 in the Test sequence the recorded reach of the unit remains as previously mapped. A number of re-attributions downstream refine the lateral extent of the terrace however, reducing the apparent elevation discrepancies seen in long profile projection. Boreholes SU50NW177 and 178 are located close to the edge of an outcrop of Terrace 6 at Locks Heath, which may indicate caution is necessary in interpreting their stratigraphic position in the Test sequence (Figure 4.33, note 14). When considered alongside borehole SU50NW214 (reassigned from Terrace 3 to Terrace 5 as discussed above) and the nearby borehole SU50NW186 (Figure 4.33, note 15) the stratigraphic position of the group would appear to be more consistent with Terrace 5 at that part of the long profile. The group is reassigned to Terrace 5 here, with the necessary adjustments made to the terrace mapping in the area (Figure 4.33).

Borehole SU50NW353 is located in Terrace 6, southwest of a level assigned to Terrace 8 (Figure 4.33, note 16). When projected onto the Test long profile, the height of the borehole appears to be more consistent with Terrace 7, and the borehole and mapping are reassigned.

Boreholes SU41SE284 (Terrace 7) and 285 and 291 (Terrace 6) are located at the boundary of the two terraces and vary in bedrock height by just 1.5 m, while ground level decreases down slope from 45.5 m to 42 m O.D.. It would appear that they either represent a single terrace or a degraded edge of Terrace 7 onto Terrace 6. There is insufficient data from the area to ascertain which attribution best fits the long profile and their original attributions are maintained here.

The amended extent of Terrace 6 in the Southampton BGS map sheet is recognised in the revised long profile projection (Figure 4.34) from records at Pauncefoot to the area around Titchfield, with its longitudinal extent unchanged. The upstream projection into the Winchester BGS map sheet would appear to be consistent with correlation with PASHCC test pits GTC03 TP1 to 4, previously mapped (Booth 2002) as Terrace 4.

Terraces 7 to 11

Apart from the adjustments mentioned above, the remainder of the sequence stays largely as originally attributed by BGS mapping. The exception is a group of boreholes (SU41SE301, 303, 306, 317, 322, 324, 368, 369 and 371) that are mapped as Terrace 9 (Figure 4.33, note 17). When plotted in the Test long profile the group project to a level above Terrace 9 further upstream, indicating that at least the northeast portion of the terrace body in which they are located is more likely attributable to Terrace 10.

The limited number of borehole records available does not provide enough detail to be sure of the attribution of Terraces 7 to 11; instead they indicate likely height ranges only. The upstream projection of Terraces 7 into the Winchester BGS map sheet would appear to be consistent with correlation with PASHCC test pits YTC03 TP1, 3 and 4, previously mapped (Booth 2002) as Terrace 4 (TP1) and 5/6 (TP 3 and 4). Terrace 8 projects upstream to PASHCC test pits SPW03 TP1 to 4, also previously mapped (Booth 2002) as Terrace 5/6. However these correlations can be stated with less confidence than with those of the lower terraces in the Test sequence.

A projection of upstream correlations between the Southampton and Winchester BGS sheets using steeper gradients (Figure 4.34b) would not appear to fit the revised stratigraphy in this study. Applying a steeper gradient to terraces 2, 3, 4 and 5 in particular produces unrealistic gradients. Such a correlation also produces a considerable elevation difference between Terraces 1 and 2 upstream, unseen elsewhere and difficult to explain. It is conceivable that Terrace 5 correlates upstream to PASHCC test pits GTC03 TP1 to 4 on altitudinal grounds, with Terrace 6 correlating with PASHCC test pits YTC03 TP1, 3 and 4 (cf. Table 4.16). This solution would be problematic for the correlation of Terrace 5 deposits at Abbotswood (SU32 SE96 to 98), as the resulting gradient would appear to be steeper than elsewhere, while the group is also altitudinally too high to be part of Terrace 4. The best fit for the data of the Test terrace stratigraphic sequence would appear to be that shown in Figure 4.34a. Correlation of the revised terrace stratigraphy of the River Test with those of the Western Solent and Bournemouth regions (Chapters 5 and 6 respectively) is assessed in Chapter 8.

Table 4.15. Synthetic borehole logs and fieldwork data in the Test Valley generated by this study. Key: BGS schemes [1] Booth (2002); [2] Edwards and Freshney (1987); PASHCC; Harding *et al.* (2012).

						Previous mapping			
Reference	East.	North.	GL	Gr Th.	Bd Ht	BGS[1 2]	PASH.	H. *et al.* (2012)	Revised terrace scheme
BRW08 L1	451358	103540	9.37	3.80	5.37	T 2 [2]	T 2	Hamble (T2)	Terrace 2
BRW08 L2	451316	103566	9.40	3.15	6.05	T 2 [2]	T 2	Hamble (T2)	Terrace 2
BRW08 L3	451239	103596	9.43	1.85	7.38	T 2 [2]	T 2	Hamble (T2)	Terrace 2
CHC SBH 1	451935	104101	12.14	4.40	7.74	T 3 [2]	T 3	Mottisfont /LW (T3)	Terrace 2
CHC SBH 2	451900	104145	15.04	3.95	11.09	T 3 [2]	T 3	Mottisfont /LW (T3)	Terrace 3
CHC SBH 3	451880	104167	15.55	3.60	11.95	T 3 [2]	T 3	Mottisfont /LW (T3)	Terrace 3
CHC SBH 4	451761	104210	15.74	3.61	12.13	T 3 [2]	T 3	Mottisfont /LW (T3)	Terrace 3
CHC SBH 5	451546	103832	10.82	4.67	6.15	T 2 [2]	T 2	Hamble (T2)	Terrace 2
CHC SBH 6	451569	103825	10.50	4.54	5.96	T 2 [2]	T 2	Hamble (T2)	Terrace 2
CHC SBH 7	451500	103840	10.90	4.44	6.46	T 2 [2]	T 2	Hamble (T2)	Terrace 2
CHC SBH 8	451485	103844	10.92	4.60	6.32	T 2 [2]	T 2	Hamble (T2)	Terrace 2
CHRD SBH 1	449684	106073	16.35	4.34	12.01	T 3 [2]	T 3	Mottisfont /LW (T3)	Terrace 3
CHRD SBH 2	449810	105821	15.81	5.39	10.42	T 3 [2]	T 3	Mottisfont /LW (T3)	Terrace 3
CHRD SBH 3	449933	105591	15.36	5.94	9.42	T 2 [2]	T 2	Hamble (T2)	Terrace 3
DUN SBH 1	432309	125701	42.10	3.64	38.46	T 2/3 [1]	T 5	Belbin (T4)	Terrace 4
DUN SBH 2	432498	125332	34.97	4.21	30.76	T 2/3 [1]	T 4	Mottisfont (T3)	Terrace 3
DUN SBH 3	432490	125289	35.74	4.32	31.42	T 2/3 [1]	T 4	Mottisfont (T3)	Terrace 3
HAP10S1	450641	106051	16.27	4.39	11.47	T 3 [2]	T 3	Mottisfont /LW (T3)	Terrace 3
NTRD SBH 1	449340	106030	16.10	3.19	12.91	T 3 [2]	T 3	Mottisfont /LW (T3)	Terrace 3
NTRD SBH 2	449320	105711	14.32	3.89	10.43	T 3 [2]	T 3	Mottisfont /LW (T3)	Terrace 3
NTRD SBH 3	449304	105434	11.94	4.22	7.72	T 2 [2]	T 2	Hamble (T2)	Terrace 2
SOB10L2	450856	103730	9.34	3.07	5.84	T 2 [2]	T 2	Hamble (T2)	Terrace 2
SOB10S1	450775	103775	9.08	2.72	6.36	T 2 [2]	T 2	Hamble (T2)	Terrace 2
SOB10S2	450856	103738	8.90	3.05	5.85	T 2 [2]	T 2	Hamble (T2)	Terrace 2
SOB10S3	450955	103701	9.43	1.77	7.66	T 2 [2]	T 2	Hamble (T2)	Terrace 2
SOB10S4	451570	103430	9.37	1.73	7.64	T 2 [2]	T 2	Hamble (T2)	Terrace 2
SOB10S5	452110	103160	9.27	2.72	6.55	T 2 [2]	T 2	Hamble (T2)	Terrace 2

						Previous mapping			
Reference	East.	North.	GL	Gr Th.	Bd Ht	BGS[1 2]	PASH.	H. *et al.* (2012)	Revised terrace scheme
WAC10S1	450647	105881	16.56	4.26	11.56	T 3 [2]	T 3	Mottisfont /LW (T3)	Terrace 3
WACPit1	450620	105895	13.37	1.00	12.37	T 3 [2]	T 3	Mottisfont /LW (T3)	Terrace 3
WACPit2	450622	105897	13.29	1.00	12.29	T 3 [2]	T 3	Mottisfont /LW (T3)	Terrace 3

Table 4.16. PASHCC (Bates *et al*. 2004, 2007; Bates and Briant 2009) section logs used in this study. Key: BGS schemes [1] Booth (2002); [2] Edwards and Freshney (1987); PASHCC; Harding *et al.* (2012).

						Previous mapping			
Reference	East.	North.	GL	Gr Th.	Bd Ht	BGS[1 2]	PASH.	H. *et al.* (2012)	Revised terrace scheme
CAMS03 TP1	459160	105640	8.45	0.70	6.05	T 2 [2]	T 2	Hamble (T2)	Terrace 2
CAMS03 TP2	459250	105700	6.21	0.30	3.71	T 2 [2]	T 2	Hamble (T2)	Terrace 2
CAMS03 TP3	458800	105430	7.71	3.20	4.16	T 2 [2]	T 2	Hamble (T2)	Terrace 2
CAMS03 TP4	458890	105500	7.41	3.25	3.91	T 2 [2]	T 2	Hamble (T2)	Terrace 2
CAMS03 TP5	459030	105610	8.08	1.20	6.58	T2	T 2	Hamble (T2)	Terrace 2
GTC03 TP1	432100	128380	57.10	1.20	55.60	T 4 [1]	T 7	Belbin (T4)	Terrace 6
GTC03 TP2	431910	128280	60.00	1.90	57.80	T 4 [1]	T 7	Belbin (T4)	Terrace 6
GTC03 TP3	432070	128340	58.75	2.25	56.10	T 4 [1]	T 7	Belbin (T4)	Terrace 6
GTC03 TP4	431970	128340	59.30	1.45	57.60	T 4 [1]	T 7	Belbin (T4)	Terrace 6
HOOK03 TP1	452360	105590	30.80	0.70	29.80	T 5 [2]	T 5	Mallards Moor (T5)	Terrace 5
HOOK03 TP2	452360	105110	25.00	0.90	22.30	T 4 [2]	T 4	Belbin (T4)	Terrace 4
HOOK03 TP3	452350	105840	33.05	0.75	31.65	T 5 [2]	T 5	Mallards Moor (T5)	Terrace 5
HUF03 TP1	434710	125130	24.65	>2.90	-	T 1 [1]	T 1	Terrace W1	Terrace 1
MTF03 TP1	432460	128410	44.73	2.15	42.18	T 2/3 [1]	T 5	Belbin (T4)	Terrace 4
MTF03 TP2	432370	128370	45.54	>4.00	-	T 2/3 [1]	T 5	Belbin (T4)	Terrace 4
MTF03 TP3	432370	128340	48.50	1.45	46.60	T 2/3 [1]	T 5	Belbin (T4)	Terrace 4
RIDGE03 S2	434210	118150	48.90	3.65	45.25	T 6 [2]	T 6	Nursling (T6)	Terrace 6
RIDGE03 TP1	434200	118280	49.00	1.30	45.70	T 6 [2]	T 6	Nursling (T6)	Terrace 6
SB03 S1	450700	103700	10.10	3.25	6.40	T 2 [2]	T 2	Hamble (T2)	Terrace 2
SPW03 TP1	431300	128370	74.45	1.00	73.20	T 5/6 [1]	T 8	Terrace 5/6	Terrace 8
SPW03 TP2	431240	128370	74.90	1.35	73.30	T 5/6 [1]	T 8	Terrace 5/6	Terrace 8
SPW03 TP3	431270	128380	74.60	0.80	73.60	T 5/6 [1]	T 8	Terrace 5/6	Terrace 8
SPW03 TP4	431240	128330	77.00	1.05	75.55	T 5/6 [1]	T 8	Terrace 5/6	Terrace 8
WARF03 TP1	437920	121640	41.75	1.20	40.00	T 5 [2]	T 5	Ganger Wood (T5)	Terrace 5
WARF03 TP2	437920	121690	41.90	0.70	40.75	T 5 [2]	T 5	Ganger Wood (T5)	Terrace 5
YTC03 TP1	431720	128370	64.30	2.20	61.45	T 4 [1]	T 7	Terrace W4	Terrace 7
YTC03 TP2	431650	128330	65.10	1.20	63.60	None	-	-	-
YTC03 TP3	431650	128340	67.00	>2.40	-	T 5/6 [1]	T 8	Terrace 5/6	Terrace 7

Reference	East.	North.	GL	Gr Th.	Bd Ht	Previous mapping BGS[1 2]	PASH.	H. *et al.* (2012)	Revised terrace scheme
YTC03 TP4	431560	128330	68.50	2.80	65.40	T 5/6 [1]	T 8	Terrace 5/6	Terrace 7
YTC03 TP5	431600	128360	67.50	0.75	66.35	None	-	-	-

Table 4.17. Bridgland and Harding (1987; Harding *et al*. 2012) section logs used in this study. Key: BGS schemes [1] Booth (2002); [2] Edwards and Freshney (1987); PASHCC; Harding *et al.* (2012).

Reference	East.	North.	GL	Gr Th.	Bd Ht	Previous mapping BGS[1 2]	PASH.	H. *et al.* (2012)	Revised terrace scheme
DUN S1	431930	125625	47.80	4.20	44.50	T 2/3[1]	T 5	Belbin (T4)	Terrace 4
DUN S13	432025	125370	46.80	-	?	T 2/3[1]	T 5	Belbin (T4)	Terrace 4
DUN S14	432255	125520	41.80	1.90	39.90	T 2/3[1]	T 4	Mottisfont (T3)	Terrace 3
DUN S15	432260	125525	42.00	-	?	T 2/3[1]	T 4	Mottisfont (T3)	Terrace 3
DUN S16	432230	125505	41.50	2.50	40.00	T 2/3[1]	T 4	Mottisfont (T3)	Terrace 3
DUN S2	432030	125630	45.70	2.60	43.80	T 2/3[1]	T 5	Belbin (T4)	Terrace 4
DUN S3	432080	125650	45.10	3.20	42.90	T 2/3[1]	T 5	Belbin (T4)	Terrace 4
DUN S4a	432155	125640	44.40	6.40	38.90	T 2/3[1]	T 5	Belbin (T4)	Terrace 4
DUN S4b	432160	125645	44.40	3.15	42.15	T 2/3[1]	T 5	Belbin (T4)	Terrace 4
DUN86S1	431940	125720	38.75	2.50	35.25	T 2/3[1]	T 4	Mottisfont (T3)	Terrace 3
DUN86S3	431665	125740	39.25	2.75	35.05	T 2/3[1]	T 4	Mottisfont (T3)	Terrace 3

Table 4.18. The available borehole archive of the Test valley used in this study. [1] Booth (2002); [2] Edwards and Freshney (1987) [3] PASHCC. Undiff.: Undifferentiated terrace level.

Reference	Easting	Northing	GL	Gr Th.	Bd Ht	Previous mapping BGS [1 2] PASHCC[3]	Harding *et al*. 2012	Revised terrace scheme
SU31NE1	436280	116110	7.04	2.13	4.30	Terrace 1	Broadlands Farm (T1)	Terrace 1
SU31NE104	437690	116740	44.87	1.98	41.36	Terrace 6	Nursling (T6)	Terrace 6
SU31NE156	438080	115370	21.67	2.82	17.94	Terrace 3	Mottisfont (T3)	Terrace 3
SU31NE172	438730	115790	33.56	4.12	29.14	Terrace 4	Belbin (T4)	Terrace 4
SU31NE173	439120	115970	44.45	1.75	42.47	Terrace 6	Nursling (T6)	Terrace 6
SU31NE174	439190	116020	45.81	4.50	41.24	Terrace 6	Nursling (T6)	Terrace 6
SU31NE19	435760	116320	5.45	2.44	-0.04	Terrace 1	Broadlands Farm (T1)	Terrace 1
SU31NE190	438740	115710	33.19	2.29	30.60	Terrace 4	Belbin (T4)	Terrace 4
SU31NE193	438870	115880	36.96	1.52	31.02	Terrace 4	Belbin (T4)	Terrace 4
SU31NE196	438190	115370	22.04	3.27	18.54	Terrace 3	Mottisfont (T3)	Terrace 3
SU31NE2	436280	115980	6.56	0.91	4.58	Terrace 1	Broadlands	Terrace 1

Reference	Easting	Northing	GL	Gr Th.	Bd Ht	Previous mapping BGS [1 2] PASHCC[3]	Harding *et al*. 2012	Revised terrace scheme
							Farm (T1)	
SU31NE20	435860	116310	8.55	3.25	4.84	Terrace 1	Broadlands Farm (T1)	Terrace 1
SU31NE208	437040	117700	25.02	1.00	22.57	Terrace 3	Mottisfont (T3)	Terrace 3
SU31NE209	436930	118250	24.10	0.70	23.10	Terrace 3	Mottisfont (T3)	Terrace 3
SU31NE21	435980	116320	8.92	4.88	3.43	Terrace 1	Broadlands Farm (T1)	Terrace 1
SU31NE210	436550	119070	14.92	3.10	9.82	Undiff. terrace	Undiff. terrace	Terrace 1
SU31NE211	436460	118290	11.97	3.50	7.97	Terrace 1	Broadlands Farm (T1)	Terrace 1
SU31NE213	436170	117510	8.74	0.70	5.24	Terrace 1	Broadlands Farm (T1)	Terrace 1
SU31NE214	436210	117130	8.66	0.80	6.46	Terrace 1	Broadlands Farm (T1)	Terrace 1
SU31NE215	436100	116730	9.30	0.50	6.60	Terrace 1	Broadlands Farm (T1)	Terrace 1
SU31NE216	435820	117780	11.90	5.10	6.50	Terrace 1	Broadlands Farm (T1)	Terrace 1
SU31NE226	436190	117360	8.50	0.90	6.70	Terrace 1	Broadlands Farm (T1)	Terrace 1
SU31NE227	435730	117290	7.40	0.10	6.80	Terrace 1	Broadlands Farm (T1)	Terrace 1
SU31NE228	435990	117350	8.20	0.40	7.60	Terrace 1	Broadlands Farm (T1)	Terrace 1
SU31NE229	436220	117170	8.80	0.20	7.40	Terrace 1	Broadlands Farm (T1)	Terrace 1
SU31NE230	435920	116930	7.40	0.90	5.60	Terrace 1	Broadlands Farm (T1)	Terrace 1
SU31NE238	435400	115760	5.64	3.45	1.09	Terrace 1	Broadlands Farm (T1)	Terrace 1
SU31NE24	436340	116350	8.51	2.14	6.07	Terrace 1	Broadlands Farm (T1)	Terrace 1
SU31NE243	436720	115710	9.01	3.90	3.26	Terrace 1	Broadlands Farm (T1)	Terrace 1
SU31NE244	436820	115710	9.45	3.80	4.85	Terrace 1	Broadlands Farm (T1)	Terrace 1
SU31NE245	436920	115710	9.90	2.90	5.40	Terrace 1	Broadlands Farm (T1)	Terrace 1
SU31NE247	436720	115600	9.01	5.00	3.51	Terrace 1	Broadlands Farm (T1)	Terrace 1
SU31NE248	436820	115610	9.25	3.10	5.25	Terrace 1	Broadlands Farm (T1)	Terrace 1
SU31NE249	436920	115600	9.50	3.50	5.00	Terrace 1	Broadlands Farm (T1)	Terrace 1
SU31NE250	437020	115610	10.89	5.25	5.14	Terrace 1	Broadlands Farm (T1)	Terrace 1
SU31NE27	436400	116340	6.99	1.53	2.72	Terrace 1	Broadlands Farm (T1)	Terrace 1
SU31NE28	436400	116300	5.69	2.28	0.97	Terrace 1	Broadlands Farm (T1)	Terrace 1
SU31NE32	437090	117650	28.15	0.61	27.08	Terrace 3	Mottisfont (T3)	Terrace 3

Reference	Easting	Northing	GL	Gr Th.	Bd Ht	Previous mapping: BGS [1 2] PASHCC[3]	Previous mapping: Harding *et al*. 2012	Revised terrace scheme
SU31NE341	438600	116070	38.18	3.20	31.58	Terrace 4	Belbin (T4)	Terrace 4
SU31NE343	438460	116010	36.76	4.50	30.06	Terrace 4	Belbin (T4)	Terrace 4
SU31NE346	439850	115070	31.39	4.58	25.29	Terrace 6	Nursling (T6)	Terrace 6
SU31NE347	439910	115010	32.69	1.83	27.20	Terrace 6	Nursling (T6)	Terrace 6
SU31NE348	439880	115000	34.06	3.35	27.96	Terrace 6	Nursling (T6)	Terrace 6
SU31NE349	439860	115030	32.23	4.27	26.13	Terrace 6	Nursling (T6)	Terrace 6
SU31NE359	436350	115990	8.23	2.21	5.87	Terrace 1	Broadlands Farm (T1)	Terrace 1
SU31NE36	437160	117160	39.22	1.37	37.39	Terrace 4	Belbin (T4)	Terrace 5
SU31NE371 G	438800	116000	41.40	0.90	40.40	Terrace 4	Belbin (T4)	Terrace 5
SU31NE371 D	438800	116000	39.60	1.00	37.70	Terrace 4	Belbin (T4)	Terrace 5
SU31NE371 E	438800	116000	40.70	0.45	40.00	Terrace 4	Belbin (T4)	Terrace 5
SU31NE388	436020	115920	7.30	0.10	4.80	Terrace 1	Broadlands Farm (T1)	Terrace 1
SU31NE40	436950	116780	26.46	1.83	24.02	Terrace 3	Mottisfont (T3)	Terrace 3
SU31NE41	436940	116670	24.29	1.83	21.85	Terrace 3	Mottisfont (T3)	Terrace 3
SU31NE44	436890	116570	21.17	1.68	18.88	Terrace 3	Mottisfont (T3)	Terrace 3
SU31NE46	436920	116570	22.32	1.22	20.03	Terrace 3	Mottisfont (T3)	Terrace 3
SU31NE47	436920	116520	21.65	0.61	20.74	Terrace 3	Mottisfont (T3)	Terrace 3
SU31NE49	437100	116620	26.06	1.22	23.93	Terrace 3	Mottisfont (T3)	Terrace 3
SU31NE5	435960	116110	6.24	1.38	3.34	Terrace 1	Broadlands Farm (T1)	Terrace 1
SU31NE6	436180	116050	6.23	0.61	5.01	Terrace 1	Broadlands Farm (T1)	Terrace 1
SU31NE66	437070	115750	11.24	3.20	6.67	Terrace 1	Broadlands Farm (T1)	Terrace 1
SU31NE7	435960	115880	5.97	1.37	3.84	Terrace 1	Broadlands Farm (T1)	Terrace 1
SU31NE70	437100	115370	10.56	1.98	6.75	Terrace 1	Broadlands Farm (T1)	Terrace 1
SU31NE71	437160	115260	8.17	1.68	6.34	Terrace 1	Broadlands Farm (T1)	Terrace 1
SU31NE73	437080	115140	9.23	2.74	5.12	Terrace 1	Broadlands Farm (T1)	Terrace 1
SU31NE74	437110	115100	9.49	3.65	4.16	Terrace 1	Broadlands Farm (T1)	Terrace 1
SU31NE80	437050	116510	23.04	1.52	21.06	Terrace 3	Mottisfont (T3)	Terrace 3
SU31NW15	432960	116380	13.53	1.37	10.18	Terrace 1	Broadlands Farm (T1)	Terrace 1
SU31NW17	432830	117070	12.99	1.60	11.08	Terrace 1	Broadlands Farm (T1)	Terrace 1

Reference	Easting	Northing	GL	Gr Th.	Bd Ht	Previous mapping: BGS [1 2] PASHCC[3]	Previous mapping: Harding *et al*. 2012	Revised terrace scheme
SU31NW19	432970	116880	13.47	3.58	9.05	Terrace 1	Broadlands Farm (T1)	Terrace 1
SU31NW24	432990	116460	13.20	0.91	10.76	Terrace 1	Broadlands Farm (T1)	Terrace 1
SU31NW26	433050	116480	12.66	1.83	10.22	Terrace 1	Broadlands Farm (T1)	Terrace 1
SU31NW27	433120	116500	12.99	1.98	9.94	Terrace 1	Broadlands Farm (T1)	Terrace 1
SU31NW28	433070	116410	13.54	4.11	8.97	Terrace 1	Broadlands Farm (T1)	Terrace 1
SU31NW29	433100	116400	13.50	3.35	9.84	Terrace 1	Broadlands Farm (T1)	Terrace 1
SU31NW53	434370	116440	6.64	2.82	3.44	Terrace 1	Broadlands Farm (T1)	Terrace 1
SU31NW54	434480	116430	6.71	2.13	4.27	Terrace 1	Broadlands Farm (T1)	Terrace 1
SU31NW94	434200	119500	48.77	3.05	45.72	Terrace 6	Nursling (T6)	Terrace 6
SU31SE263	439820	114990	38.56	4.54	33.99	Terrace 6	Nursling (T6)	Terrace 6
SU31SE264	439870	114990	36.42	6.10	30.02	Terrace 6	Nursling (T6)	Terrace 6
SU31SE265	439840	114820	37.19	0.76	35.82	Terrace 4	Belbin (T4)	Terrace 4
SU31SE266	439550	114980	38.40	4.27	33.68	Terrace 4	Belbin (T4)	Terrace 4
SU31SE267	439550	114980	36.42	1.68	29.41	Terrace 4	Belbin (T4)	Terrace 4
SU32NW11	431560	126260	26.50	0.00	22.30	Terrace W1	Terrace W1	Terrace W1
SU32NW12	431510	126230	26.40	0.00	22.60	Terrace W1	Terrace W1	Terrace W1
SU32NW13	431300	126070	24.90	2.40	20.00	Terrace W1	Terrace W1	Terrace W1
SU32NW7	432680	126320	22.30	4.65	15.55	Terrace W1	Terrace W1	Terrace W1
SU32SE17	438300	122600	42.67	1.38	40.99	Terrace 5	Ganger Wood (T5)	Terrace 5
SU32SE20	435500	121390	14.63	4.88	8.54	Undiff. terrace	Undiff. terrace	Terrace 1
SU32SE21	435250	121440	16.76	4.88	10.36	Undiff. terrace	Undiff. terrace	Terrace 1
SU32SE5	435170	122840	17.93	7.20	10.38	Terrace 1	Broadlands Farm (T1)	Terrace 1
SU32SE96	436660	123390	48.00	2.00	44.00	Terrace W4	Terrace W4	Terrace W5
SU32SE97	436570	123090	44.00	2.00	40.90	Terrace 4	Terrace 4	Terrace 5
SU32SE98	436530	123240	44.00	3.40	40.60	Terrace W4	Terrace W4	Terrace W5
SU32SW10	434920	122710	17.13	6.45	9.38	Terrace 1	Broadlands Farm (T1)	Terrace 1
SU32SW3	434630	123180	20.67	3.50	16.07	Terrace W1	Terrace W1	Terrace W1
SU32SW4	434340	123500	21.69	3.50	17.19	Terrace W1	Terrace W1	Terrace W1
SU32SW8	434990	123170	19.75	3.40	15.65	Terrace W1	Terrace W1	Terrace W1

						Previous mapping		
Reference	Easting	Northing	GL	Gr Th.	Bd Ht	BGS [1 2] PASHCC[3]	Harding *et al*. 2012	Revised terrace scheme
SU32SW9	434920	123000	19.64	3.25	15.39	Terrace 1	Broadlands Farm (T1)	Terrace 1
SU40NE12	446985	107070	14.33	1.52	9.15	Terrace 2	Hamble (T2)	Terrace 2
SU40NE13	447740	107020	17.37	3.81	12.95	Terrace 3	Belbin (T4)	Terrace 3
SU40NE14	447710	106965	17.07	2.13	14.33	Terrace 3	Belbin (T4)	Terrace 3
SU40NE15	447490	106480	6.10	2.89	0.92	Terrace 2	Hamble (T2)	Terrace 2
SU40NE16	447520	106555	6.55	3.66	1.98	Terrace 2	Hamble (T2)	Terrace 2
SU40NE17	447465	106460	4.88	1.07	2.29	Terrace 2	Hamble (T2)	Terrace 2
SU40NE18	447490	106450	5.79	4.42	0.46	Terrace 2	Hamble (T2)	Terrace 2
SU40NE19	447865	106290	5.79	1.52	3.66	Terrace 2	Hamble (T2)	Terrace 2
SU40NE44	446510	107800	16.00	4.57	11.43	Terrace 3	Belbin (T4)	Terrace 3
SU40NE56	449780	108190	33.53	1.52	32.01	Terrace 5	Mallards Moor (T5)	Terrace 5
SU40NE6	446375	107785	11.89	5.03	6.86	Terrace 2	Hamble (T2)	Terrace 2
SU40NE87	446930	107080	14.33	3.35	9.15	Terrace 2	Hamble (T2)	Terrace 2
SU40NE88	446360	107760	11.89	4.88	7.01	Terrace 2	Hamble (T2)	Terrace 2
SU40NE91	447860	106280	5.79	1.52	3.66	Terrace 2	Hamble (T2)	Terrace 2
SU40NE92	447710	106960	17.07	2.74	13.72	Terrace 3	Belbin (T4)	Terrace 3
SU40NW68	443930	105790	16.64	2.90	13.75	Terrace 2	Hamble (T2)	Terrace 2
SU40NW69	443890	105840	15.48	1.83	13.35	Terrace 2	Hamble (T2)	Terrace 2
SU40NW70	443880	105890	13.20	1.52	11.37	Terrace 2	Hamble (T2)	Terrace 2
SU40NW71	443950	105860	13.11	3.20	9.22	Terrace 2	Hamble (T2)	Terrace 2
SU40NW72	443980	105840	13.99	7.01	6.68	Terrace 2	Hamble (T2)	Terrace 2
SU40NW77	444060	105920	8.99	2.74	5.79	Terrace 2	Hamble (T2)	Terrace 2
SU40NW80	444020	105880	10.79	3.96	6.22	Terrace 2	Hamble (T2)	Terrace 2
SU40NW83	444000	105960	8.81	7.09	1.11	Terrace 2	Hamble (T2)	Terrace 2
SU40NW86	444020	106030	6.40	9.14	-3.05	Terrace 2	Hamble (T2)	Terrace 2
SU40NW87	443960	105990	8.81	12.04	-3.69	Terrace 2	Hamble (T2)	Terrace 2
SU40NW89	443870	105990	10.67	3.96	6.40	Terrace 2	Hamble (T2)	Terrace 2
SU40NW91	443920	105950	10.70	1.52	8.87	Terrace 2	Hamble (T2)	Terrace 2
SU41NW146	441500	117520	79.36	2.74	76.31	Terrace 10	Toot Hill (T11)	Terrace 10
SU41NW175	442580	116780	67.32	0.46	66.56	Terrace 9	Rownhams Farm (T8)	Terrace 9
SU41NW471	440280	115800	50.20	1.10	48.60	Terrace 7	Bitterne (T7)	Terrace 7
SU41NW472	440250	115800	50.54	1.70	48.04	Terrace 7	Bitterne (T7)	Terrace 7
SU41NW473	440280	115780	49.99	0.85	48.49	Terrace 7	Bitterne (T7)	Terrace 7
SU41NW474	440300	115820	50.45	1.00	48.75	Terrace 7	Bitterne (T7)	Terrace 7
SU41NW506	442480	115160	42.28	1.68	40.45	Terrace 6	Nursling (T6)	Terrace 6
SU41NW634	442400	116827	73.70	0.90	72.60	Terrace 9	Rownhams Farm (T8)	Terrace 9
SU41NW635	442462	116781	71.10	0.30	70.60	Terrace 9	Rownhams Farm (T8)	Terrace 9
SU41NW636	442520	116750	68.50	1.70	66.45	Terrace 9	Rownhams Farm (T8)	Terrace 9
SU41NW637	442575	116723	66.40	0.80	65.40	Terrace 9	Rownhams Farm (T8)	Terrace 9

Reference	Easting	Northing	GL	Gr Th.	Bd Ht	Previous mapping BGS [1 2] PASHCC[3]	Harding *et al*. 2012	Revised terrace scheme
SU41NW665	442212	117683	81.60	1.00	80.50	Terrace 10	Toot Hill (T11)	Terrace 10
SU41NW666	442238	117706	81.40	0.35	80.90	Terrace 10	Toot Hill (T11)	Terrace 10
SU41NW672	441210	116030	60.96	3.35	57.61	Terrace 8	Rownhams Farm (T8)	Terrace 8
SU41NW680	442650	115490	43.28	0.91	41.91	Terrace 6	Nursling (T6)	Terrace 6
SU41NW82	441790	118080	86.65	3.05	83.60	Terrace 11	Lordswood Lane (T12)	Terrace 11
SU41SE223	447070	111890	57.94	3.05	54.59	Terrace 8	Rownhams Farm (T8)	Terrace 8
SU41SE284	447740	110340	45.50	2.00	41.50	Terrace 7	Bitterne (T7)	Terrace 7
SU41SE285	447820	110330	43.30	1.25	41.30	Terrace 6	Nursling (T6)	Terrace 6
SU41SE291	447870	110250	42.00	1.50	40.00	Terrace 6	Nursling (T6)	Terrace 6
SU41SE301	448070	112060	74.17	1.40	72.37	Terrace 9	Netley Hill (T11)	Terrace 10
SU41SE303	448090	111860	75.05	2.60	72.05	Terrace 9	Netley Hill (T11)	Terrace 10
SU41SE306	448170	112330	75.30	0.20	74.80	Terrace 9	Netley Hill (T11)	Terrace 10
SU41SE317	448170	111840	70.83	0.60	69.73	Terrace 9	Netley Hill (T11)	Terrace 10
SU41SE322	448050	112180	76.41	2.90	73.31	Terrace 9	Netley Hill (T11)	Terrace 10
SU41SE324	448030	112140	75.41	0.40	74.31	Terrace 9	Netley Hill (T11)	Terrace 10
SU41SE368	446580	113090	74.00	1.00	72.70	Terrace 9	West End (T12)	Terrace 10
SU41SE369	446530	113100	75.00	0.60	74.00	Terrace 9	West End (T12)	Terrace 10
SU41SE371	446520	113020	75.00	1.30	73.10	Terrace 9	West End (T12)	Terrace 10
SU41SE380	446300	110640	33.60	0.80	31.90	Terrace 5	Mallards Moor (T5)	Terrace 5
SU41SE564	447110	111552	55.00	1.98	51.95	Terrace 8	Rownhams Farm (T8)	Terrace 8
SU41SE567	447212	111489	54.75	2.59	49.87	Terrace 8	Rownhams Farm (T8)	Terrace 8
SU41SW10	442060	113260	25.10	3.80	19.00	Terrace 4	Belbin (T4)	Terrace 4
SU41SW133	441800	112030	13.93	3.33	10.60	Terrace 3	Mottisfont (T3)	Terrace 3
SU41SW134	441800	112030	13.98	3.33	10.65	Terrace 3	Mottisfont (T3)	Terrace 3
SU41SW135	441760	112090	14.68	0.20	10.98	Terrace 3	Mottisfont (T3)	Terrace 3
SU41SW179	441730	113170	24.50	2.80	21.30	Terrace 4	Belbin (T4)	Terrace 4
SU41SW198	442040	113240	25.18	2.20	21.08	Terrace 4	Belbin (T4)	Terrace 4
SU41SW30	442020	113250	25.20	2.80	20.10	Terrace 4	Belbin (T4)	Terrace 4
SU41SW31	442090	113230	25.60	3.18	21.70	Terrace 4	Belbin (T4)	Terrace 4
SU41SW319	441930	111270	9.14	0.61	4.57	Terrace 2	Hamble (T2)	Terrace 2
SU41SW429	444770	110180	22.86	3.05	19.81	Terrace 4	Belbin (T4)	Terrace 4

Reference	Easting	Northing	GL	Gr Th.	Bd Ht	Previous mapping: BGS [1 2] PASHCC[3]	Previous mapping: Harding *et al*. 2012	Revised terrace scheme
SU41SW431	440980	112290	10.88	2.35	6.43	Terrace 2	Hamble (T2)	Terrace 2
SU41SW432	441000	112280	10.91	4.80	5.11	Terrace 2	Hamble (T2)	Terrace 2
SU41SW433	440990	112260	10.85	2.30	7.15	Terrace 2	Hamble (T2)	Terrace 2
SU41SW434	440970	112230	10.22	2.50	7.12	Terrace 2	Hamble (T2)	Terrace 2
SU41SW435	441000	112230	10.96	2.85	7.11	Terrace 2	Hamble (T2)	Terrace 2
SU41SW439	441030	112260	11.31	4.35	5.96	Terrace 2	Hamble (T2)	Terrace 2
SU41SW440	441030	112220	11.28	2.35	7.68	Terrace 2	Hamble (T2)	Terrace 2
SU41SW476	441980	114050	36.40	0.50	35.40	Terrace 6	Nursling (T6)	Terrace 5
SU41SW477	442000	114050	37.11	1.50	35.31	Terrace 6	Nursling (T6)	Terrace 5
SU41SW505	442740	111770	3.10	3.80	-2.10	Terrace 1	Broadlands Farm (T1)	Terrace 1
SU41SW51	441970	113230	24.54	2.40	20.64	Terrace 4	Belbin (T4)	Terrace 4
SU41SW630	442030	112910	24.30	1.90	20.20	Terrace 4	Belbin (T4)	Terrace 4
SU41SW631	442060	112910	24.30	3.50	19.80	Terrace 4	Belbin (T4)	Terrace 4
SU41SW632	442080	112920	24.20	6.90	16.40	Terrace 4	Belbin (T4)	Terrace 4
SU41SW633	442070	112880	24.30	1.50	21.80	Terrace 4	Belbin (T4)	Terrace 4
SU41SW634	442040	112880	24.10	1.20	20.10	Terrace 4	Belbin (T4)	Terrace 4
SU41SW676	444690	110180	22.86	3.05	19.81	Terrace 4	Belbin (T4)	Terrace 4
SU41SW681 A	440530	113010	16.46	2.44	14.02	Terrace 3	Mottisfont (T3)	Terrace 3
SU41SW681 B	440530	113010	16.46	3.35	13.11	Terrace 3	Mottisfont (T3)	Terrace 3
SU41SW802	444816	111159	28.20	4.05	23.35	Terrace 4	Belbin (T4)	Terrace 4
SU41SW870	440770	114020	25.31	2.40	22.91	Terrace 4	Belbin (T4)	Terrace 4
SU41SW871	440800	114020	25.33	1.70	23.23	Terrace 4	Belbin (T4)	Terrace 4
SU41SW94	442670	111950	4.24	6.55	-3.23	Terrace 1	Broadlands Farm (T1)	Terrace 1
SU41SW97	442260	111460	5.18	3.35	-0.92	Terrace 1	Broadlands Farm (T1)	Terrace 1
SU41SW98	442260	111420	4.82	2.29	0.25	Terrace 1	Broadlands Farm (T1)	Terrace 1
SU41SW99	442280	111430	4.69	2.29	-0.34	Terrace 1	Broadlands Farm (T1)	Terrace 1
SU50NW172 /1	453100	107200	42.90	1.80	39.70	Terrace 6	Nursling (T6)	Terrace 6
SU50NW172 /2	453100	107200	42.90	2.20	40.20	Terrace 6	Nursling (T6)	Terrace 6
SU50NW177	451070	107000	37.63	3.40	33.63	Terrace 6	Nursling (T6)	Terrace 5
SU50NW178	451060	106960	36.27	3.00	32.77	Terrace 6	Nursling (T6)	Terrace 5
SU50NW186	450600	108060	35.05	3.05	32.00	Terrace 6	Nursling (T6)	Terrace 5
SU50NW197	452060	107600	43.34	0.00	41.44	Terrace 6	Nursling (T6)	Terrace 6
SU50NW207	451290	105690	16.22	2.50	13.52	Terrace 3	Belbin (T4)	Terrace 3
SU50NW214	451800	106230	28.66	1.80	25.86	Terrace 3	Belbin (T4)	Terrace 5
SU50NW226	452260	107350	43.40	5.70	37.20	Terrace 6	Nursling (T6)	Terrace 6

Reference	Easting	Northing	GL	Gr Th.	Bd Ht	Previous mapping: BGS [1 2] PASHCC[3]	Previous mapping: Harding *et al*. 2012	Revised terrace scheme
SU50NW229	452300	107250	43.05	5.40	36.75	Terrace 6	Nursling (T6)	Terrace 6
SU50NW230	452200	107340	43.20	5.40	37.00	Terrace 6	Nursling (T6)	Terrace 6
SU50NW231	452230	107250	42.80	5.30	37.00	Terrace 6	Nursling (T6)	Terrace 6
SU50NW232	452270	107300	43.30	5.30	37.00	Terrace 6	Nursling (T6)	Terrace 6
SU50NW323	450870	106239	20.24	4.40	15.84	Terrace 3	Belbin (T4)	Terrace 4
SU50NW324	450800	106282	20.24	3.10	16.94	Terrace 3	Belbin (T4)	Terrace 4
SU50NW325	450769	106332	20.38	3.00	17.08	Terrace 3	Belbin (T4)	Terrace 4
SU50NW326	450761	106410	20.79	2.50	18.29	Terrace 3	Belbin (T4)	Terrace 4
SU50NW327	450728	106481	21.59	2.40	18.19	Terrace 3	Belbin (T4)	Terrace 4
SU50NW328	450729	106511	22.17	2.50	19.67	Terrace 3	Belbin (T4)	Terrace 4
SU50NW329	450728	106600	22.99	1.80	21.19	Terrace 3	Belbin (T4)	Terrace 4
SU50NW331	450602	106670	25.42	3.70	19.72	Terrace 3	Belbin (T4)	Terrace 4
SU50NW332	450615	106596	23.74	2.80	19.34	Terrace 3	Belbin (T4)	Terrace 4
SU50NW333	450470	106600	23.51	1.68	19.03	Terrace 3	Belbin (T4)	Terrace 4
SU50NW334	450480	106686	24.10	3.20	19.20	Terrace 3	Belbin (T4)	Terrace 4
SU50NW335	450347	106880	22.90	5.80	16.90	Terrace 3	Belbin (T4)	Terrace 4
SU50NW336	450232	106810	22.27	5.20	16.77	Terrace 3	Belbin (T4)	Terrace 4
SU50NW343	450480	106515	22.00	1.40	18.60	Terrace 3	Belbin (T4)	Terrace 4
SU50NW353	450530	108570	48.10	3.10	43.10	Terrace 6	Nursling (T6)	Terrace 7
SU50NW463	453270	106800	37.36	5.00	31.46	Terrace 5	Mallards Moor (T5)	Terrace 5
SU50NW467	453320	106890	37.91	2.96	34.95	Terrace 5	Mallards Moor (T5)	Terrace 5
SU50NW469	453240	106760	37.08	1.94	35.14	Terrace 5	Mallards Moor (T5)	Terrace 5
SU50NW470	453240	106860	38.40	1.90	36.50	Terrace 5	Mallards Moor (T5)	Terrace 5
SU50NW471	453260	106970	39.41	1.40	38.01	Terrace 5	Mallards Moor (T5)	Terrace 5
SU50NW473	453320	106710	34.91	2.98	31.93	Terrace 5	Mallards Moor (T5)	Terrace 5
SU50SE148	456810	101530	10.50	0.50	9.40	Terrace 2	Hamble (T2)	Terrace 2
SU50SE356	456320	101470	7.88	0.95	5.63	Terrace 2	Hamble (T2)	Terrace 2
SU50SE357	456430	101480	7.76	4.50	2.16	Terrace 2	Hamble (T2)	Terrace 2
SU50SE81	458260	101330	6.80	0.76	2.53	Terrace 2	Hamble (T2)	Terrace 2
SU50SE82	458300	101290	6.86	1.68	2.29	Terrace 2	Hamble (T2)	Terrace 2
SU50SE92	456970	102550	7.46	1.75	4.96	Terrace 2	Hamble (T2)	Terrace 2
SU50SE95	457030	101410	7.65	3.45	3.85	Terrace 2	Hamble (T2)	Terrace 2
SU50SE96	457290	100810	4.79	3.50	0.59	Terrace 2	Hamble (T2)	Terrace 2
SU50SW16	451970	104090	11.55	2.10	8.25	Terrace 3	Mottisfont (T3)	Terrace 2
SU50SW21	451590	104010	13.40	2.10	10.90	Terrace 2	Hamble (T2)	Terrace 3
SU50SW23	450350	104230	8.40	1.95	6.20	Terrace 2	Hamble (T2)	Terrace 2
SU50SW26	450980	104430	13.00	5.00	8.00	Terrace 2	Hamble (T2)	Terrace 3
SU50SW27	450920	104240	10.67	4.27	5.49	Terrace 2	Hamble (T2)	Terrace 2

Reference	Easting	Northing	GL	Gr Th.	Bd Ht	Previous mapping: BGS [1 2] PASHCC[3]	Previous mapping: Harding *et al*. 2012	Revised terrace scheme
SZ59NE10	456800	099700	3.20	2.81	-0.91	Terrace 2	Hamble (T2)	Terrace 2
SZ59NE12	456820	099680	4.72	5.18	-0.46	Terrace 2	Hamble (T2)	Terrace 2
SZ59NE18	457540	099830	5.73	3.90	-0.37	Undiff	Hamble (T2)	Terrace 2
SZ59NE21	458100	099440	0.61	0.50	-6.09	Terrace 2	Hamble (T2)	Terrace 2
SZ59NE31	457590	099780	5.73	3.90	-0.37	Undiff.	Undiff.	Terrace 2
SZ59NE34	458120	099410	0.61	0.50	-6.09	Terrace 2	Hamble (T2)	Terrace 2
SZ59NE39	459850	099590	6.10	1.98	3.66	Terrace 2	Hamble (T2)	Terrace 2
SZ59NE4	458800	099500	4.40	2.80	-4.90	Terrace 2	Hamble (T2)	Terrace 2
SZ59NE9	458730	099050	4.94	4.80	-0.32	Terrace 2	Hamble (T2)	Terrace 2
SZ69NW202	462280	099730	3.05	0.38	-0.23	Terrace 2	Hamble (T2)	Terrace 2
SZ69NW203	462230	099600	2.77	4.72	-3.02	Terrace 2	Hamble (T2)	Terrace 2
SZ69NW207	460600	098100	4.90	7.40	-3.30	Terrace 2	Hamble (T2)	Terrace 2
SZ69NW208	460600	098100	4.83	5.70	-1.27	Terrace 2	Hamble (T2)	Terrace 2
SZ69NW209	460600	098100	4.52	5.30	-1.28	Terrace 2	Hamble (T2)	Terrace 2
SZ69NW210	460600	098100	4.65	5.85	-1.60	Terrace 2	Hamble (T2)	Terrace 2
SZ69NW42	461360	098590	4.56	0.30	-0.74	Terrace 2	Hamble (T2)	Terrace 2
SZ69NW43	461320	098620	4.60	0.90	-1.50	Terrace 2	Hamble (T2)	Terrace 2
SZ69NW46	461210	098670	3.27	1.80	-3.43	Terrace 2	Hamble (T2)	Terrace 2
SZ69NW47	461140	098570	3.48	1.10	-1.02	Terrace 2	Hamble (T2)	Terrace 2
SZ69NW48	461090	098530	3.01	1.95	-0.24	Terrace 2	Hamble (T2)	Terrace 2

CHAPTER FIVE: THE WESTERN SOLENT

5.1 Introduction

Remnant Pleistocene fluvial gravels of the former Solent River survive in the Western Solent as extensive deposits between Barton on Sea and Southampton Water (Figure 5.1). A staircase of terrace levels extends from the New Forest plateau in the north of the region to the shoreline of the current Solent. Fourteen terraces are recognised in the mapping schemes of both Allen and Gibbard (1993) and Westaway *et al*. (2006), although there are a number of correlation differences between them (see Chapter 2.5). These issues are outlined in sections 5.2, 5.3 and 5.4 below.

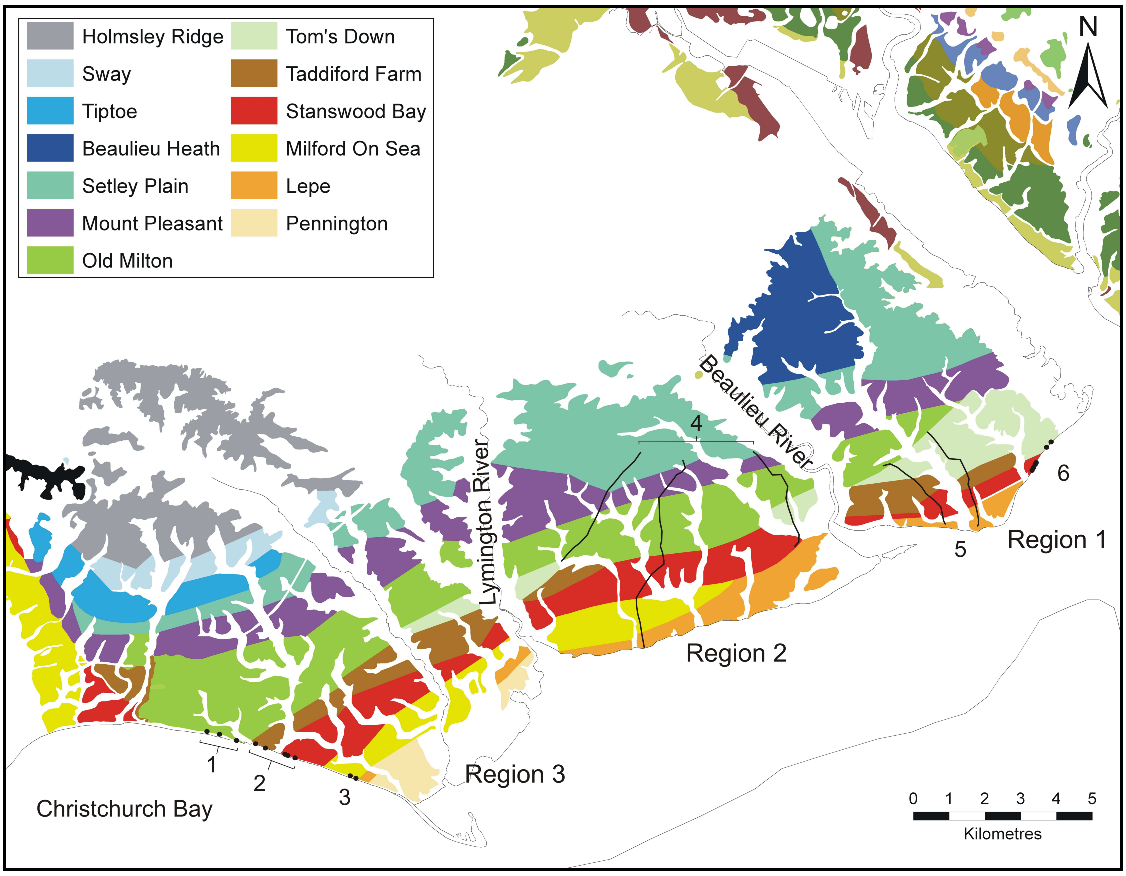


Figure 5.1. Location map of fieldwork sites and terrace attributions (Allen and Gibbard (1993) scheme) in the Western Solent region. Fieldwork sites are numbered: 1. Barton on Sea (coastal section recording). 2. Hordle Cliff (coastal section recording and OSL). 3. Milford on Sea (coastal section recording and OSL). 4. Region 2 GPR. 5. Region 1 GPR. 6. Stanswood Bay (coastal section recording).

The Western Solent has been divided by tributary river courses into three regions (Figure 5.1) for the ease of presentation and interpretation of the data in this study. Fieldwork was undertaken at Stanswood Bay, Lepe and Exbury, in the Beaulieu and

Lymington regions, and along the coastal section of Christchurch Bay between Barton on Sea and Milford on Sea (Figure 5.1). Sites for investigation were selected primarily with the aim of providing additional data through excavation, coastal section recording and ground penetrating radar (GPR) where previous work, particularly borehole coverage, was lacking. Data generated by section recording and GPR is summarised by the generation of synthetic boreholes as described in Chapter 3.6 (Methods). The results of these investigations are presented below, along with an examination of the available borehole record in the region.

Specific research aims identified for the Western Solent region were: A) to better understand the stratigraphy of the extensive terrace deposits in the Western Solent; B) to determine how the Western Solent terraces correlate with the lower Test terraces (as seen at Warsash and Solent Breezes, Chapter 4); C) to establish the age of some key Western Solent terraces; and D) to produce a revised stratigraphic model of the fluvial terraces of the Western Solent region. In order to attempt to address these research aims a variety of methods were utilised in a multi- technique approach. Laterally extensive coastal sections were recorded at Stanswood Bay and between Barton on Sea and Milford on Sea using a Topcon Imaging Station and vertical sedimentary logs were also recorded where sections were accessible. These data contribute to better defining the Western Solent terrace stratigraphy and how it relates to the lower Test sequence (aims A and B). Samples for optically stimulated luminescence (OSL) dating were taken from sand lenses within coastal sections between Barton on Sea and Milford on Sea where they were deemed suitable. Data produced by the OSL method contributed to determining the age of key Western Solent terraces (Aim C) and how the Western Solent terrace stratigraphy relates to the lower Test sequence (aims B). GPR surveys were conducted at various locations around Exbury and Lepe, and between the Beaulieu and Lymington Rivers. Data produced by GPR investigation enabled a clearer definition of the Western Solent terrace stratigraphy and how it relates to the lower Test sequence (aims A and B). The available borehole record of the Western Solent region was examined alongside data produced during fieldwork. This dataset was used to construct long profile projections of the Western Solent terrace stratigraphy which would contribute to better defining the Western Solent stratigraphic sequence and how it correlates with the lower Test sequence (aims A and B). Finally, all of the analyses carried out in the Western Solent

Region contributed to the production of a revised stratigraphic model of the fluvial terraces of the Western Solent region (Aim D). Fieldwork and data analyses were carried out as described in Chapter 3 (Methods).

5.2 The Western Solent Region 1

5.2.1 Previous work: The Western Solent Region 1

Region 1 of the Western Solent study area comprises the fluvial deposits preserved between Solent Water to the east and the Beaulieu River to the west. The mapping schemes of Allen and Gibbard (1993) and Westaway *et al*. (2006) identified nine and eight terrace units respectively (Table 5.1), with intermediate terraces seen at the west end of the Western Solent region not present here. The lowest terrace body is defined as the Lepe terrace in both schemes, while there is similar agreement on the Beaulieu Heath designation for the altitudinally highest terrace. However there is little agreement on the intermediate terrace sequence (Table 5.1). Allen and Gibbard (1993) designate the eastern half of Westaway *et al*.'s (2006) Beaulieu Heath terrace as Setley Plain, which extends to the south to correlate with the former scheme's Mount Pleasant terrace.

Table 5.1. A comparison of the terrace models currently describing the deposits in the Western Solent Region 1.

Allen and Gibbard (1993) model		Westaway *et al.* (2006) model		Bridgland (1996, 2001) MIS	MIS based on OSL (Briant *et al.* 2006)
Terrace	MIS	Terrace	MIS		
Beaulieu Heath	?	Beaulieu Heath	13b	13	-
Setley Plain	?	Mount Pleasant	12	12	-
Mount Pleasant	?	Old Milton	10	11	-
Old Milton	?	Becton Farm	9b	-	-
Tom's Down	?	Tom's Down	8	10	8-9
Taddiford Farm	?			9	
Stanswood Bay	?	Stanswood Bay	7b	8	8-7b
Lepe (lower)	Pre 7	Lepe (lower)	Late 6	?7b-e	7d-6
Stone Point, Lepe	7	Stone Point, Lepe	5e	7a	5e
Lepe (upper)	6	Lepe (upper)	5d-2	6	5d-3

The next three terrace bodies in the sequence are mapped more or less to the same geometry, although the steeper gradients of Allen and Gibbard's (1993) scheme results in the correlation of their Mount Pleasant terrace with Westaway *et al*.'s (2006) Old Milton, similarly their Old Milton with Becton Farm, while the Tom's

Down terrace is mostly agreed upon. The next terrace body, Allen and Gibbard's (1993) Taddiford Farm, is not recognised by Westaway *et al*. (2006), who divide the terrace between the higher Tom's Down terrace and the lower Stanswood Bay terrace.

As discussed in Chapter 2.4 the interglacial sediments at Pennington Marshes (Allen *et al.* 1996), Stone Point, Lepe (West and Sparks 1960; Brown *et al.* 1975; Green and Keen 1987; Briant *et al.* 2009c) and St Leonards Farm (Mathers 1982b; Briant *et al.* 2013) have received recent attention. The most recent interpretation of the Stone Point sequence (Briant *et al*. 2009c) supports a last interglacial (MIS 5e) attribution based on OSL dating of lower and upper gravels. Stratigraphically that interpretation is problematic due to the presence of last interglacial sediments at Pennington Marshes (Allen *et al.* 1996) which appear to be upstream and yet attributable to a lower terrace level

5.2.2 Stratigraphy and sedimentology: Stanswood Bay

The coastal section at Stanswood Bay (SU 470 000) is the stratotype locality of Allen and Gibbard's (1993) Stanswood Bay terrace. Current stratigraphic models also indicate an exposure of an altitudinally distinct (and higher) gravel body along the bay to the east, assigned to the Tom's Down terrace by both Allen and Gibbard (1993) and Westaway *et al*. (2006). Six sections of fluvial gravels were recorded by imaging station or total station (STB10 S1 to S6, producing synthetic boreholes), while two sedimentary logs were described where physical access to sections was possible (STB10 L1 and STB10 L5). As recorded in synthetic boreholes STB SBH1 to 6, sands and gravels in the Stanswood Bay coastal section were found to range from around 1.4 m to 3.5 m in thickness. Beneath the Stanswood Bay terrace bedrock heights range from 4 m to 5.3 m O.D., while for the two locations in the Tom's Down terrace average bedrock contact height is around 9.5 m O.D. In terms of the height differential of terraces in the Western Solent region, a 4 to 5 m change in bedrock contact O.D. in the Stanswood Bay coastal section, over a relatively short lateral distance, would appear to indicate the presence of two distinct deposits at this locality. Stratigraphic data from Stanswood Bay is collated in Table 5.2 at the end of the section.

Sections STB10 S1 to S4 record stratigraphic detail in the same gravel deposit as described below in STB10 L1, identified as Stanswood Bay. The terrace is exposed along the coastal section for more than 400 m, and locations to record were chosen based on the presence of bedrock exposure and fluvial gravels. STB10 S1 (Figure 5.2) consists of around 10 m of exposed bedrock overlain by around 3.5 m to nearly 4 m of interbedded sands and sandy gravels. Bedrock contact height varies little along the section, with a slight gradient rising to the east. Bedrock contact height is at 5.28 m O.D. as recorded in STB SBH1. The terrace thickness is 3.53 m, capped by a 0.22 m of topsoil. Ground level is recorded at 9.03 m O.D. The section's ground level trend decreases from west to east.

STB10 S2 (Figure 5.2) records a bedrock exposure of around 6.8 m in length. The west end of the bedrock profile may indicate the edge of a channel or other erosional feature, although the exposure is limited. Bedrock contact height is at 4.12 m O.D. as recorded in STB SBH2. Sands and gravels are 2.92 m in thickness and are capped by 0.17 m of topsoil. Ground level is recorded at 7.21 m O.D.

STB10 S3 (Figure 5.2) has a more extensive exposure of bedrock contact of nearly 30 m. The relatively horizontal profile of the bedrock surface appears to show a number of possible small scour features. Bedrock contact height is at 4.38 m O.D. as recorded in STB SBH3. The thickness of the terrace body is 1.5 m, covered with 0.49 m of topsoil. Ground level is recorded at just 6.37 m at the location of SBH3. At the east end of the profile both the terrace surface and ground level rises to around 7.2 m and 7.4 m respectively.

STB10 S4 (Figure 5.2) is the final section recorded in the Stanswood Bay terrace. 20 m of bedrock is exposed and as in STB10 S1 and STB10 S3 has a relatively horizontal surface profile with some localised variation in height. Bedrock height is at 4.01 m O.D. as recorded in STB SBH4. The Stanswood Bay terrace is at its thinnest at this end of the coastal section, being 1.37 m in thickness in SBH4. Topsoil is 0.28 m thick and ground level is recorded at 5.66 m O.D.

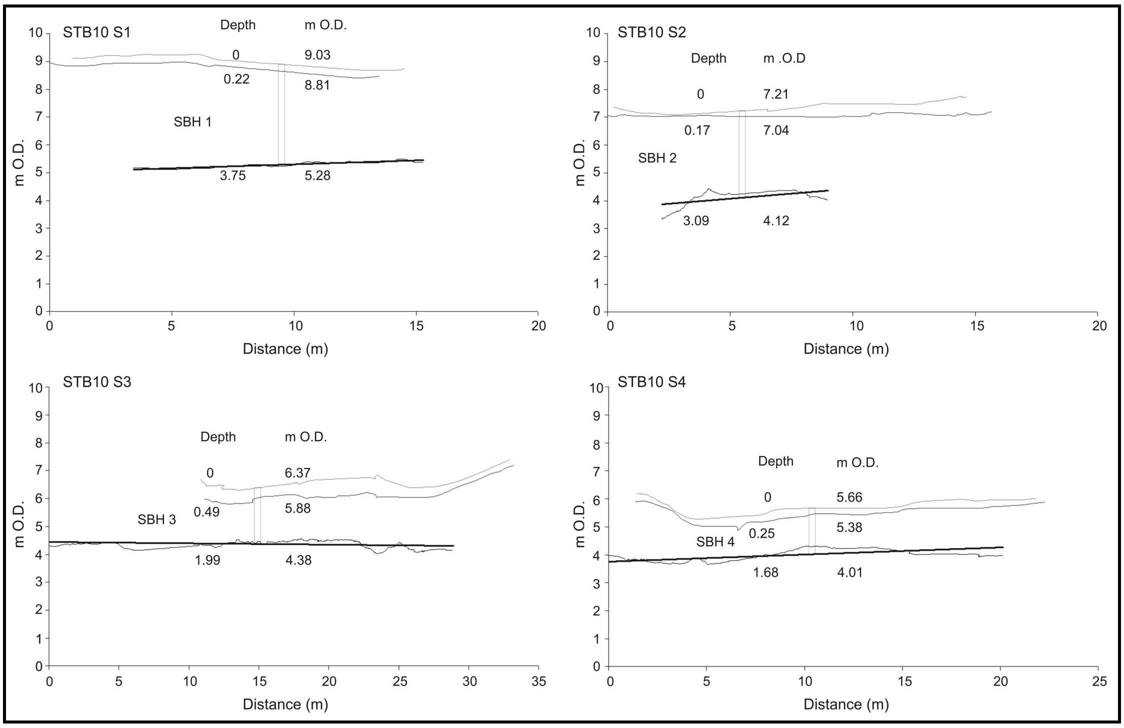


Figure 5.2. Bedrock height (with trend line), terrace surface height and ground level of coastal sections STB10 S1, S2, S3 and S4 recorded at Stanswood Bay. Synthetic boreholes STB SBH 1, 2, 3 and 4 locations and heights also shown. The terrace is attributed to Stanswood Bay (Allen and Gibbard 1993; Westaway *et al.* 2006).

Sections STB10 S5 and S6 record stratigraphic detail in the same gravel deposit as described below in STB10 L5, identified as Tom's Down. The terrace is only seen in limited locations along the coastal section, and as such there was insufficient exposure to make full use of the imaging station.

STB10 S6 (Figure 5.3) was the most extensive exposure of the Tom's Down terrace found at Stanswood Bay, although it still amounted to only around 4 m in length. Vegetation immediately in front of the section prevented the use of the optical scanning of the imaging station but it was possible to survey a number of heights using the total station function. STB SBH6 records bedrock contact height at 9.78 m O.D., with a terrace thickness of 1.36 m. Topsoil is 0.48 m thick, with ground level at 11.62 m O.D.

STB10 S5 (Figure 5.3) was the only other accessible location where the contact between bedrock and the Tom's Down terrace was visible. The section was heavily weathered in the upper metre or so, making it difficult to ascertain terrace height and ground level. The data presented in Figure 5.3 consists of an imaging station survey of the bedrock contact height, with maximum and minimum heights for terrace surface and ground level again surveyed manually. STB SBH5 records bedrock height at 9.33 m O.D., with a terrace thickness of 2.01 m. Topsoil is 0.38 m thick, with ground level at 11.72 m O.D.

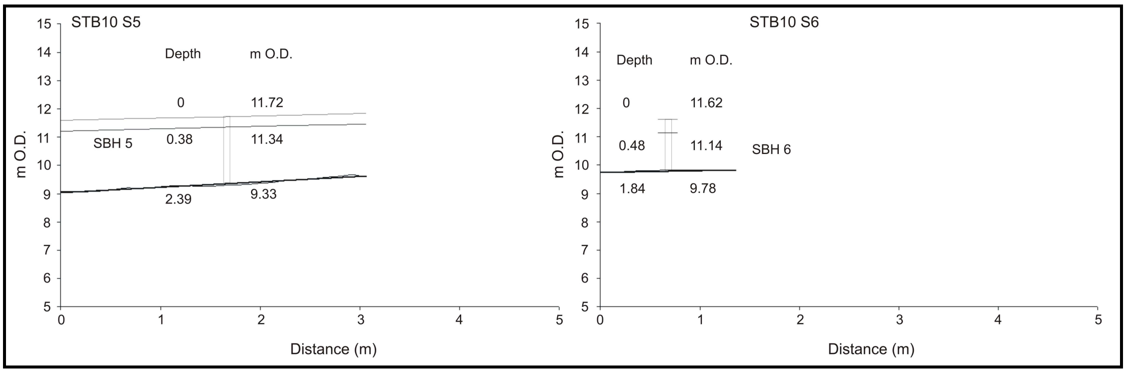
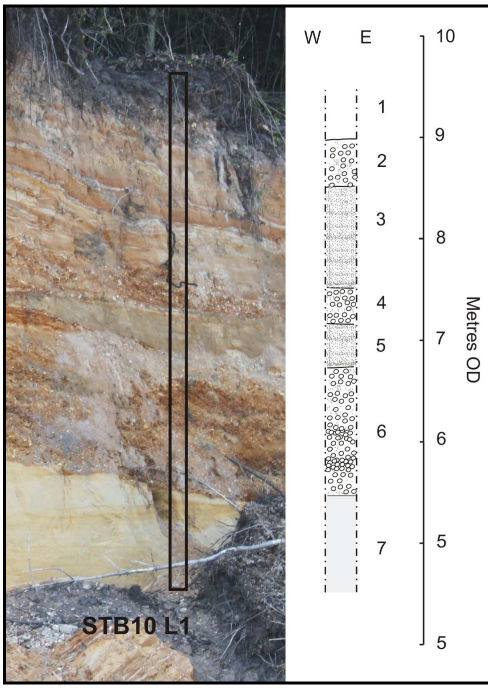


Figure 5.3. Bedrock height (with trend line), terrace surface height and ground level of coastal sections STB10 S5 and S6 recorded at Stanswood Bay. Synthetic boreholes STB SBH 5 and 6 locations and heights also shown. The terrace is attributed to Tom's Down (Allen and Gibbard 1993; Westaway *et al*. 2006).

Table 5.2. Synthetic borehole data from Imaging Station sections in Western Solent region 1. The current terrace attributions of Allen and Gibbard (1993) and Westaway *et al*. (2006) are shown.

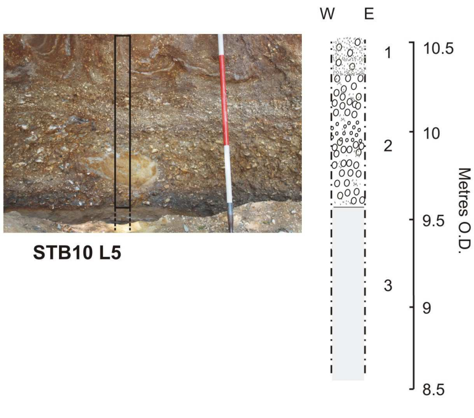
Reference	Easting	Northing	Ground level (m O.D.)	Gravel thickness (m)	Bedrock height (m O.D.)	Terrace: Allen & Gibbard	Terrace: Westaway *et al.*
STB SBH 1	447388	100486	9.03	3.53	5.28	Stanswood Bay	Stanswood Bay
STB SBH 2	447398	100595	7.21	2.92	4.12	Stanswood Bay	Stanswood Bay
STB SBH 3	447406	100665	6.37	1.50	4.38	Stanswood Bay	Stanswood Bay
STB SBH 4	447451	100702	5.66	1.37	4.01	Stanswood Bay	Stanswood Bay
STB SBH 5	447780	101042	11.72	2.01	9.33	Tom's Down	Tom's Down
STB SBH 6	447807	101029	11.62	1.36	9.78	Tom's Down	Tom's Down

STB L1 (SZ 47388 00486) (Figure 5.4) is located within the Stanswood Bay terrace. Bedrock in the area is the Barton Sand, a reddish yellow fine to medium sand. Bedrock contact height in L1 is recorded as 5.41 m O.D. A sequence of interbedded sandy gravels and sand deposits 3.53 m thick makes up the Stanswood Bay terrace here. A 1.3 m-thick deposit of sandy gravels erosionally overlies the Barton Sand, consisting of sub-angular to sub-rounded clasts in a medium sand matrix. Gravels are very fine to coarse, generally poorly sorted but with some horizontal bedding. At around 5.61 m O.D. a moderately sorted clast supported band around 10 cm thick consists of medium to coarse gravels. A 0.4 m thick iron-stained bed of medium sand with some horizontal bedding is next in the sequence, followed by a 0.33 m thick deposit of poorly sorted fine to coarse sandy gravel and a 1.0 m thick medium sand bed with some horizontal bedding. A final moderately sorted sandy gravel is then capped by topsoil.



Bed	Description	Depth top	m OD	Thickness
1	TOPSOIL.	0.00	9.38	0.44
2	SANDY GRAVEL. Fine to medium sandy gravel; moderately sorted; clasts rounded to angular; sharp lower boundary; [out of reach]	0.44	8.94	0.50
3	SAND. Medium sand; some horizontal bedding; yellow (2.5Y 7/6); diffuse lower boundary.	0.94	8.44	1.00
4	SANDY GRAVEL. Fine to coarse sandy gravel; clasts angular to sub-angular; poorly sorted; reddish yellow (7.5YR 7/8); sharp lower boundary.	1.94	7.44	0.33
5	SAND. Medium sand; some horizontal bedding [PIC]; iron stained in places; pale yellow (2.5Y 8/2); sharp lower boundary.	2.27	7.11	0.40
6	SANDY GRAVEL. Very fine to coarse sandy gravel; clasts sub-angular to sub-rounded; medium sand matrix; some horizontal bedding; clast supported bands c.5 to 10cm thick; reddish yellow (7.5YR 6/8); sharp lower boundary.	2.67	6.71	1.30
7	SAND. Compact fine/fine to medium sand; reddish yellow (7.5YR 8/6). (Barton Sand)	3.97	5.41	1.00
	End of log	4.97	4.41	-

Figure 5.4. Sedimentary log STB L1.



Bed	Description	Depth top	m OD	Thickness
1	PEBBLY, CLAYEY SAND. Fine to medium pebbly, clayey sand; clasts very fine to medium, sub-angular to sub-rounded; moderately sorted in places; occasional lenses/patches of medium sand; iron staining in places with light grey (2.5Y 7/1) sand; matrix supported; yellowish red (5YR 5/8); diffuse lower boundary.	0.00	10.52	0.20
2	SANDY GRAVEL. Very fine to coarse (coarsening downward) sandy gravel; matrix supported; clasts rounded to sub-angular; generally poorly sorted; moderately sorted, horizontally bedded lens of very fine to fine gravel c.7cm thick; very poorly sorted lower 40cm contains lense of reddish yellow (7.5YR 7/8) fine sand [?Barton Sand]; slightly clayey fine to occasionally medium sand matrix; light reddish brown (2.5YR 6/4); sharp lower boundary.	0.20	10.32	0.78
3	SAND. Fine/fine to medium sand; reddish yellow (7.5YR 8/6). (Barton Sand)	0.98	9.54	1.00
	End of log	1.98	8.54	-

Figure 5.5. Sedimentary log STB L5.

STB L5 (SZ 47807 01029) (Figure 5.5) is situated within the Tom’s Down terrace. Bedrock at the locality, as described in STB L1, is Barton Sand. The section was heavily weathered in the upper metre or so, making sedimentary description difficult.

Accessible in the section was a basal sandy gravel with fine to medium clasts coarsening downward, 0.78 m thick. A 0.2 m thick pebbly clayey sand conformably overlies the gravel. The sequence above this point was eroded at the location of L5.

5.2.3 Ground Penetrating Radar: Exbury to Lepe

A GPR survey was carried out in the Western Solent Region 1, where two transects were recorded (Figure 5.6) along suitable roads that descended through the terrace stratigraphy. Transect locations were chosen in order to cover as much of the terrace stratigraphy of Region 1 as possible. To obtain the longest possible unbroken GPR dataset, transects were carried out along minor tarmac roads. This enabled multiple terrace levels (and areas of transition between terrace levels) to be investigated easily and quickly, although the approach limited available locations for transects. The two transects surveyed four of the lower terrace levels in the scheme of Allen and Gibbard (1993) (Lepe, Stanswood Bay, Taddiford Farm and Tom’s Down) and three according to Westaway *et al*. (2006) (Lepe, Stanswood Bay and Tom’s Down) in Region 1.

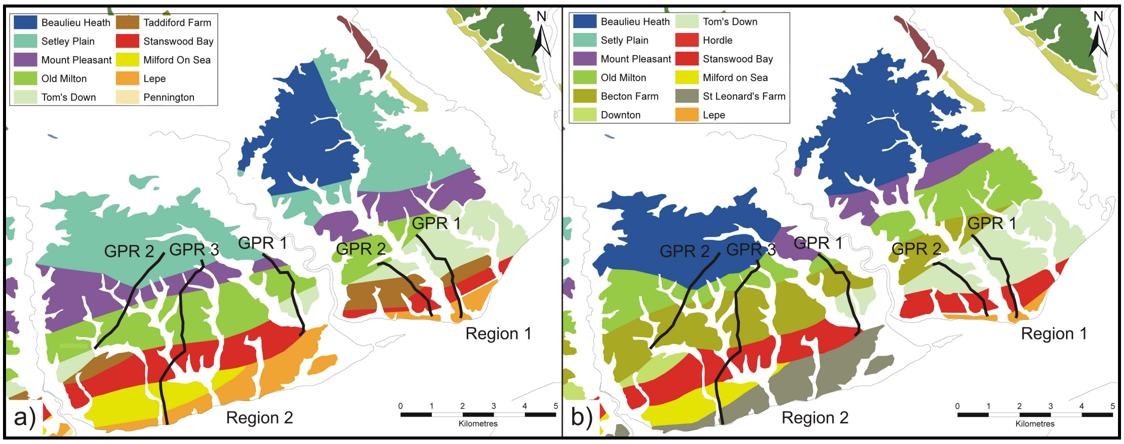


Figure 5.6. Location map of GPR transects in Western Solent Regions 1 and 2. Terrace stratigraphy of a) Allen and Gibbard (1993), b) Westaway *et al*. (2006).

The Exbury and Lepe transects were the first to be conducted for this study. Initial surveys in the area were conducted using a 100 MHz antenna (see Chapter 3.4.3), which proved to generate insufficient depth penetration to consistently reach bedrock. Therefore limited data was generated from these GPR surveys. There were locations however where bedrock contact could be detected and elevation data determined.

Transect 1 began at Whitefield Farm (SU 448 006), just south of Langley, and continued to Lepe Country Park (SZ 455 985). Synthetic boreholes (Table 5.3) were generated at points where possible terrace levels were identified in the GPR trace.

Table 5.3. Synthetic borehole data from GPR transect 1 in Western Solent region 1. The current terrace attributions of Allen and Gibbard (1993) and Westaway *et al*. (2006) are shown.

Reference	Easting	Northing	Ground level (m O.D.)	Terrace thickness (m)	Bedrock height (m O.D.)	Terrace: Allen & Gibbard	Terrace: Westaway *et al.*
WSOL11 1	445145	100030	16.05	3.10	12.95	Tom's Down	Tom's Down
WSOL11 2	445491	099703	9.81	3.23	6.58	Stanswood Bay	Stanswood Bay
WSOL11 3	445774	098715	4.47	3.08	1.39	Lepe	Lepe

Transect 2 began to the west of Lepe village (SZ 444 987) and continued to the village of Exbury (SU 427 001). Synthetic boreholes (Table 5.4) were generated at points where possible terrace levels were identified in the GPR trace.

Table 5.4. Synthetic borehole data from GPR transect 2 in Western Solent region 1. The current terrace attributions of Allen and Gibbard (1993) and Westaway *et al*. (2006) are shown.

Reference	Easting	Northing	Ground level (m O.D.)	Terrace thickness (m)	Bedrock height (m O.D.)	Terrace: Allen & Gibbard	Terrace: Westaway *et al.*
WSOL12 1	443265	100409	21.20	3.25	17.95	Old Milton	Becton Farm
WSOL12 2	444190	099875	14.86	2.81	12.05	Taddiford Farm	Tom's Down
WSOL12 3	444692	099170	10.19	2.90	7.29	Stanswood Bay	Stanswood Bay
WSOL12 4	444927	098715	3.76	2.45	1.31	Lepe	Lepe

5.3 The Western Solent Region 2

5.3.1 Previous work: The Western Solent Region 2

Region 2 of the Western Solent study area comprises the fluvial deposits preserved between the Beaulieu River to the east and the Lymington River to the west. The mapping schemes of Allen and Gibbard (1993) and Westaway *et al*. (2006) both identified eight terrace units in the region (Table 5.5), although the schemes differ considerably in their attribution and correlation of terraces. Intermediate terraces seen at the west end of the Western Solent region are not present in this region. The lowest terrace unit present is defined as the Lepe terrace by Allen and Gibbard (1993) and St Leonards Farm by Westaway *et al*. (2006). There is broad agreement on the subsequent two terraces as Milford on Sea and Stanswood Bay, and a deposit of Tom's Down to the east of the region. To the West, Allen and Gibbard's (1993) Taddiford Farm terrace correlates with Westaway *et al*.'s (2006) Downton terrace, and the former's Tom's Down outcrop is incorporated into the latter's Becton Farm. Elsewhere in the region the Becton Farm terrace correlates with Allen and Gibbard's (1993) Old Milton terrace. The last two terrace levels broadly agree in their geometry, and are identified as Mount Pleasant followed by Setley Plain in the nomenclature of Allen and Gibbard (1993) and Old Milton/ Beaulieu Heath respectively in that of Westaway *et al*. (2006). The intermediate terrace in the Westaway *et al*. (2006) scheme, their Mount Pleasant, only appears in a limited extent just south of Beaulieu, an area in Allen and Gibbard's (1993) Setley Plain.

Table 5.5. A comparison of the terrace models currently describing the deposits in the Western Solent Region 2.

Allen and Gibbard (1993) model		Westaway *et al.* (2006) model		Bridgland (1996, 2001) MIS	MIS based on OSL (Briant *et al.* 2006)
Terrace	MIS	Terrace	MIS		
Setley Plain	?	Beaulieu Heath	13b	13	-
		Mount Pleasant	12	12	-
Mount Pleasant	?	Old Milton	10	11	-
Old Milton	?	Becton Farm	9b	-	-
Tom's Down	?	Downton/ Tom's Down	8	10	8-9
Taddiford Farm	?			9	
Stanswood Bay	?	Stanswood Bay	7b	8	8-7b
Milford on Sea	?	Milford on Sea	6	?7b-e	-
Lepe (lower)	Pre 7	St Leonards Farm (lower)	Late 6	?7b-e	7d-6

5.3.2 Ground Penetrating Radar: Lymington to Beaulieu

The GPR survey carried out in the Western Solent Region 2 recorded three transects (Figure 5.6) along roadside verges and suitable tarmac roads where possible. Transect locations were again chosen in order to cover as much of the terrace staircase of Region 2 as possible. Multiple terrace levels (and areas of transition between terrace levels) were investigated. The three transects surveyed each terrace level in the schemes of Allen and Gibbard (1993) and Westaway *et al*. (2006) in Region 2, with the exception of the latter's Downton terrace. In total 15.7 km of GPR data were obtained across Region 2, with surveys conducted as described in Chapter 3.5

(Methods) and synthetic boreholes generated from that data as described in Chapter 3.6.

Transect 1

Transect 1 (Figure 5.7) began at Bunkers Hill (SU 385 015), just south of Beaulieu, and continued to St Leonards Grange (SZ 405 981). Synthetic boreholes (Table 5.6) were generated at points where possible terrace levels were identified in the GPR trace.

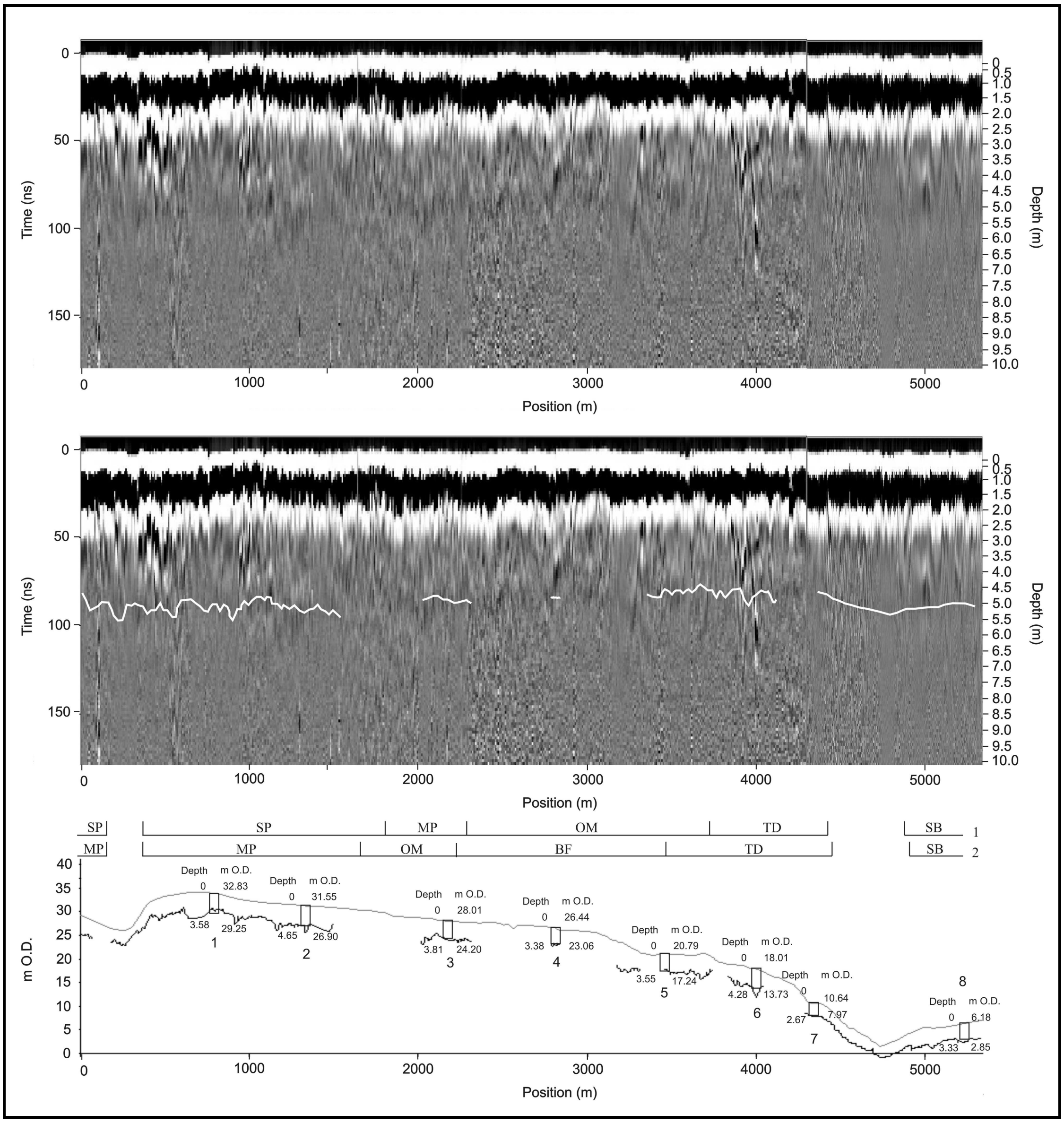


Figure 5.7. North to south GPR trace output of Transect 1 at WSOL Region 2 (top) with interpretation of bedrock contact (middle). Bottom image is a profile of GPR Transect 1 with locations of SBH 1 to 8. Terrace nomenclature: SP Setley Plain; MP Mount Pleasant; OM Old Milton; BF Becton Farm; TD Tom's Down SB Stanswood Bay. Stratigraphic model 1: Allen and Gibbard 1993; 2: Westaway *et al*. 2006.

Table 5.6. Synthetic borehole data generated from GPR transect 1 in the Western Solent region 2. The current terrace attributions of Allen and Gibbard (1993) and Westaway *et al*. (2006) are shown.

Reference	Easting	Northing	Ground level (m O.D.)	Terrace thickness (m)	Bedrock height (m O.D.)	Terrace: Allen & Gibbard	Terrace: Westaway *et al.*
WSOL21 1	438677	101056	32.83	3.58	29.25	Setley Plain	Mount Pleasant
WSOL21 2	439271	100810	31.55	4.65	26.90	Setley Plain	Mount Pleasant
WSOL21 3	439673	100324	28.01	3.81	24.20	Mount Pleasant	Old Milton
WSOL21 4	440099	100092	26.44	3.38	23.06	Old Milton	Becton Farm
WSOL21 5	440372	099484	20.79	3.55	17.24	Old Milton	Becton Farm or Tom’s Down
WSOL21 6	440495	099166	18.01	4.28	13.73	Tom’s Down	Tom’s Down
WSOL21 7	440561	098830	10.64	2.67	7.97	Tom’s Down	Tom’s Down
WSOL21 8	440510	097993	6.18	3.33	2.85	Stanswood Bay	Stanswood Bay

Transect 2

Transect 2 began on Beaulieu Heath (SU 363 008) and continued to the village of Portmore (SZ 339 973). Synthetic boreholes (Table 5.7) were generated at points where possible terrace levels were identified in the GPR trace.

Table 5.7. Synthetic borehole data generated from GPR transect 2 in the Western Solent region 2. The current terrace attributions of Allen and Gibbard (1993) and Westaway *et al*. (2006) are shown.

Reference	Easting	Northing	Ground level (m O.D.)	Terrace thickness (m)	Bedrock height (m O.D.)	Terrace: Allen & Gibbard	Terrace: Westaway *et al.*
WSOL22 1	435764	100173	39.13	4.42	34.71	Setley Plain	Beaulieu Heath
WSOL22 2	435380	099751	38.60	4.55	34.05	Setley Plain	Mount Pleasant
WSOL22 3	435212	099328	30.50	3.70	26.80	Mount Pleasant	Old Milton
WSOL22 4	434815	098498	28.35	4.10	24.25	Old Milton	Becton Farm
WSOL22 5	434357	098050	27.22	4.99	22.23	Old Milton	Becton Farm

Transect 3

Transect 3 (Figure 5.8) began at East Boldre (SU 373 005), just south of Beaulieu, and reached the shoreline at Pylewell Point (SZ 364 952). Synthetic boreholes (Table 5.8) were generated at points where possible terrace levels were identified in the GPR trace.

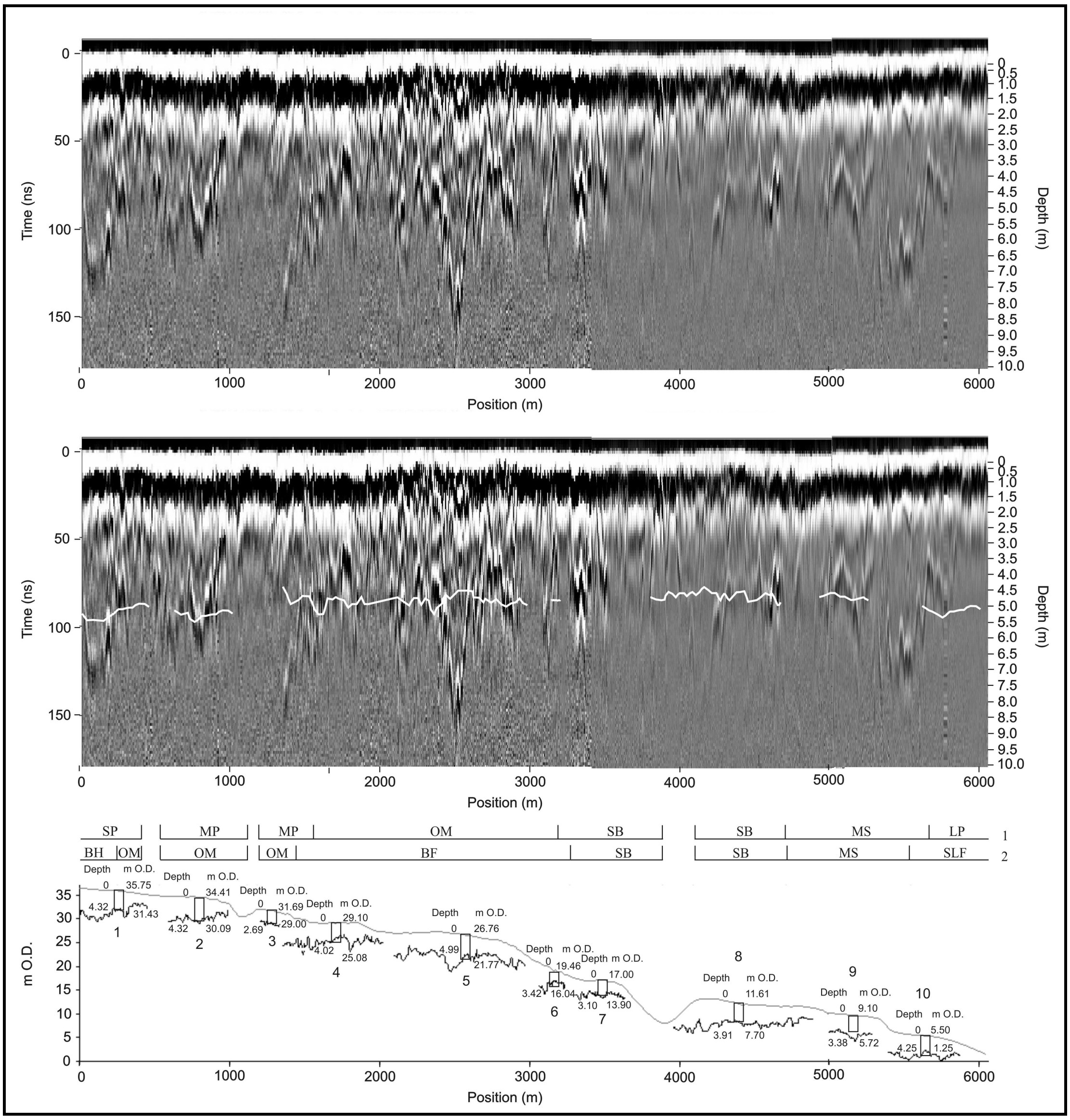


Figure 5.8. North to south GPR trace output of Transect 3 at WSOL Region 2 (top) with interpretation of bedrock contact (middle). Bottom image is a profile of GPR Transect 3 and locations of SBH 1 to 10. Terrace nomenclature: SP Setley Plain; BH Beaulieu Heath; MP Mount Pleasant; OM Old Milton; BF Becton Farm; SB Stanswood Bay; MOS Milford on Sea; LEP Lepe; SLF St Leonards Farm. Stratigraphic model 1: Allen and Gibbard 1993; 2: Westaway *et al*. 2006.

Table 5.8. Synthetic borehole data generated from GPR transect 3 in the Western Solent region 2. The current terrace attributions of Allen and Gibbard (1993) and Westaway *et al*. (2006) are shown.

Reference	Easting	Northing	Ground level (m O.D.)	Terrace thickness (m)	Bedrock height (m O.D.)	Terrace: Allen & Gibbard	Terrace: Westaway *et al.*
WSOL23 1	437407	100519	35.75	4.32	31.43	Setley Plain	Old Milton
WSOL23 2	437137	100036	34.41	4.32	30.09	Mount Pleasant	Old Milton
WSOL23 3	436864	099669	31.69	2.69	29.00	Mount Pleasant	Old Milton
WSOL23 4	436834	099257	29.10	4.02	25.08	Old Milton	Becton Farm
WSOL23 5	436817	098412	26.76	4.99	21.77	Old Milton	Becton Farm
WSOL23 6	436845	097805	19.46	3.42	16.04	Stanswood Bay	Stanswood Bay
WSOL23 7	436809	097529	17.00	3.10	13.90	Stanswood Bay	Stanswood Bay
WSOL23 8	436120	096639	11.61	3.91	7.70	Stanswood Bay	Stanswood Bay
WSOL23 9	436298	096004	9.10	3.38	5.72	Milford on Sea	Milford on Sea
WSOL23 10	436391	095560	5.50	4.25	1.25	Lepe	Lepe

5.4 The Western Solent Region 3

5.4.1 Previous work: The Western Solent Region 3

Region 3 of the Western Solent study area comprises the fluvial deposits preserved between the Lymington River to the east and the River Avon to the west. The mapping schemes of Allen and Gibbard (1993) and Westaway *et al*. (2006) each identified 11 terrace units (Table 5.9), although the schemes differ considerably in their attribution and correlation of terraces. The lowest terrace body present is defined as the Pennington terrace in both schemes. Westaway *et al*.'s (2006) Rook Cliff terrace incorporates parts of Allen and Gibbard's (1993) Pennington and Lepe terraces and a small part of the next highest Milford on Sea terrace, which is otherwise largely the same in spatial extent according to each scheme. The Stanswood Bay terrace here is also more or less mapped as the same gravel unit in either scheme, although it is referred to locally as the Hordle terrace by Westaway *et al*. (2006), and extends slightly further north. Allen and Gibbard's (1993) Taddiford Farm terrace, as elsewhere in the Western Solent, is correlated with Westaway *et al*.'s (2006) Downton terrace. A small unit of Tom's Down to the east of the region is similarly correlated with the Downton terrace. The next terrace in the sequence, Allen and Gibbard's (1993) Old Milton, is divided by Westaway *et al*. (2006) into the Becton Farm and Old Milton terraces. The latter terrace correlates with Allen and Gibbard's (1993) Mount Pleasant terrace in the east of the region due to the different projection angles used, which likewise accounts for the slight difference in orientation of the final three terraces in the sequence. The Setley Plain, Tiptoe and Sway terrace units are otherwise of similar spatial extent in the two schemes.

Table 5.9. A comparison of the terrace models currently describing the deposits in the Western Solent Region 3.

Allen and Gibbard (1993) model		Westaway *et al.* (2006) model		Bridgland (1996, 2001) MIS	MIS based on OSL (Briant *et al.* 2006)
Terrace	MIS	Terrace	MIS		
Sway	?	Sway	-	-	-
Tiptoe	?	Tiptoe	-	-	-
Setley Plain	?	Setley Plain	13b	13	-
Mount Pleasant	?	Mount Pleasant	12	12	-
Old Milton	?	Old Milton	10	11	-
		Becton Farm	9b		
Tom's Down	?	Downton	8	10	8-9
Taddiford Farm	?			9	
Stanswood Bay	?	Hordle	7b	8	8-7b
Milford on Sea	?	Milford on Sea	6	?7b-e	-
Lepe (lower)	Pre 7	Rook Cliff/ St Leonards Farm (lower)	Late 6	?7b-e	7d-6
Pennington (lower)	6	Pennington (lower)	Late 6	6	-
Pennington Marshes	5e	Pennington Marshes	5e	5e	5e
Pennington (upper)	5d-2	Pennington (upper)	5d-2	5d-2	5d-3

5.4.2 Stratigraphy and sedimentology: Milford on Sea area

The coastal section at Milford on Sea (SZ 283 915) is recorded as an exposure of the Milford on Sea terrace by both Allen and Gibbard (1993) and Westaway *et al*. (2006). Two sections of fluvial gravels were measured by imaging station (ROO11 S1 and S2). As recorded in synthetic boreholes ROO SBH1 and SBH2 (Figure 5.11), sands and gravels in the Rook Cliff coastal section are around 2.0 m to 4.5 m in thickness. Bedrock contact height is around 9.6 m O.D.

ROO11 S1 (Figure 5.9) consists of over 20 m of exposed bedrock overlain by around 1 m to nearly 3 m of sands and gravels. The topography of the bedrock surface is highly variable, ranging between around 9 m to 10 m O.D. Similarly, the terrace surface varies between around 11 m O.D. to over 12 m O.D. (and shows much modification) with ground level ranging from around 11.7 m O.D. to 12.4 m O.D. ROO11 S2 (Figure 5.9) has a more limited bedrock exposure of around 10 m. The bedrock surface is of similar variability to S1, again ranging from between around 9 m to 10 m O.D. Sands and gravels are up to 5 m in thickness, substantially more than in ROO11 S1, and are capped by around 0.5 m of topsoil. Ground level is not discernable due to vegetation cover, and as such an average height O.D. of 14.66 m has been projected to the location of ROO SBH2.

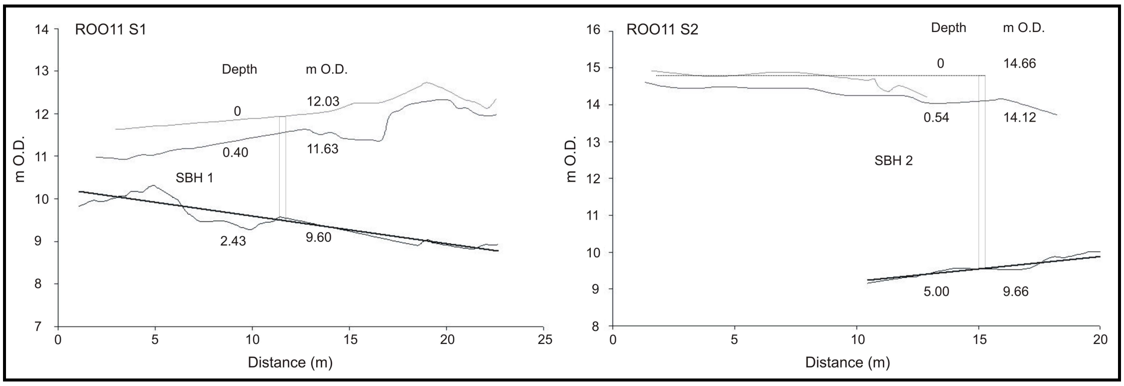


Figure 5.9. Bedrock height (with trend line), terrace surface height and ground level of coastal sections ROO11 S1 and S2 recorded at Rook Cliff (Milford on Sea). Synthetic boreholes ROO SBH 1 and 2 locations and heights also shown. The terrace is attributed to Milford on Sea (Allen and Gibbard 1993)/ Milford on Sea (Westaway *et al*. 2006).

5.4.3 Stratigraphy and sedimentology: Taddiford Gap East

The coastal section to the east of Taddiford Gap (northwest of Milford on Sea) (SZ 264 922) is the locality of Westaway *et al*.'s (2006) Hordle terrace (based on a stratotype at Hordle House (MAR borehole SZ29SE4)), the western equivalent of Allen and Gibbard's (1993) Stanswood Bay terrace. Two sections of fluvial gravels were measured by imaging station (HOR11 S1 and S2). Synthetic boreholes HOR SBH1 and SBH2 (Figure 5.10) record sands and gravels in the Hordle Cliff coastal section being around 3.2 m to 4.0 m in thickness. Bedrock contact height varies from 19.1 m to 20.1 m O.D.

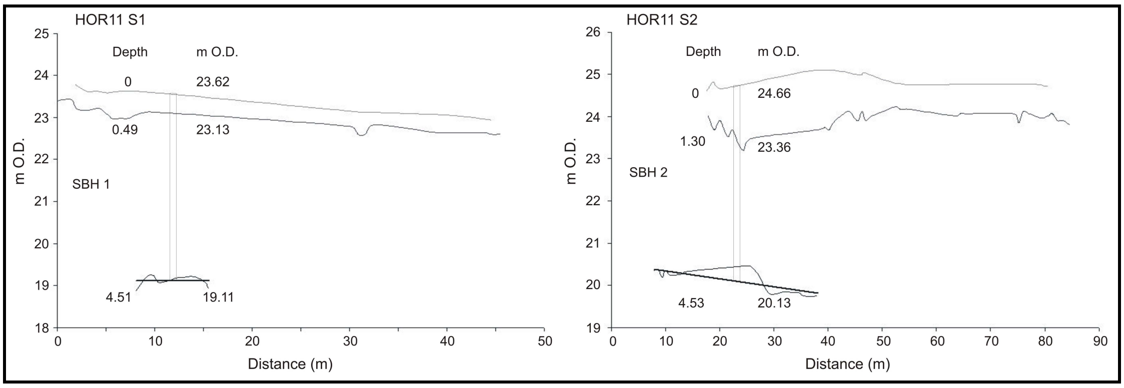


Figure 5.10. Bedrock height (with trend line), terrace surface height and ground level of coastal sections HOR11 S1 and S2 recorded at Hordle Cliff (Taddiford Gap East). Synthetic boreholes HOR SBH 1 and 2 locations and heights also shown. The terrace is attributed to Stanswood Bay (Allen and Gibbard 1993)/ Stanswood Bay (Westaway *et al*. 2006).

5.4.4 Stratigraphy and sedimentology: Taddiford Gap West

The coastal section to the west of Taddiford Gap (northwest of Milford on Sea) (SZ 255 925) is recorded as an exposure of Taddiford Farm by Allen and Gibbard (1993) and Downton by Westaway *et al*. (2006). Two sections of fluvial gravels were measured by imaging station (BAR11 S4 and S5) (Figure 5.11), while two sedimentary logs were described where samples were taken for OSL analysis (TFM11 L1A and L1B). Synthetic boreholes BAR SBH4 and SBH5 record sands and gravels in the Barton Cliff coastal section being around 3.1 m to 4.1 m in thickness. Bedrock contact height is around 22.6 m O.D. and 20.4 m O.D. Logs TFM11 L1A and L1B record bedrock at 21.6 and 21.5 m O.D. respectively, underlying around 3 m of sands and gravels. The bedrock contact height is similar to that seen in the Stanswood Bay terrace (20.1 m O.D. to 19.1 m O.D.) at Hordle Cliff as discussed above.

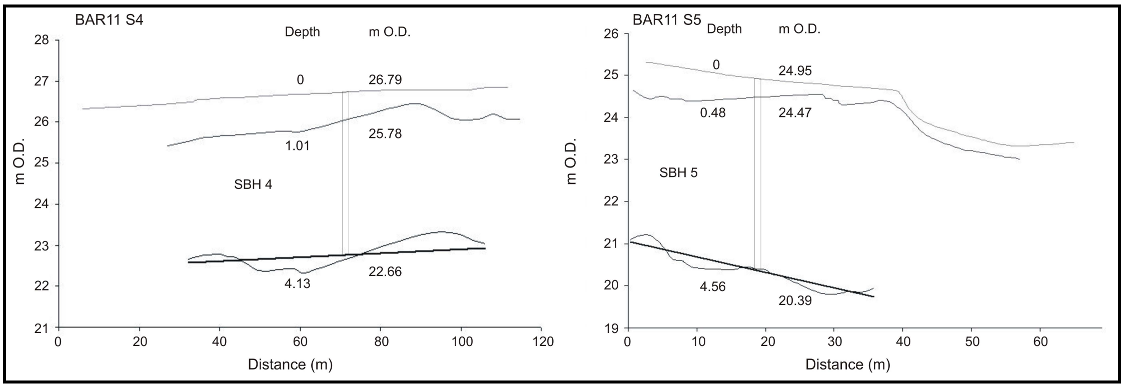


Figure 5.11. Bedrock height (with trend line), terrace surface height and ground level of coastal sections BAR11 S4 and S5 recorded at Barton Cliff (Taddiford Gap West). Synthetic boreholes BAR SBH 4 and 5 locations and heights also shown. The terrace is attributed to Taddiford Farm (Allen and Gibbard 1993)/ Downton (Westaway *et al*. 2006).

5.4.5 Stratigraphy and sedimentology: Barton on Sea

The coastal section at Barton on Sea (SZ 242 928) is the type locality of Allen and Gibbard's (1993) Old Milton terrace. It is attributed to Becton Farm by Westaway *et al*. (2006), in whose scheme the Old Milton terrace is one terrace altitudinally higher (and is equivalent to Allen and Gibbard's (1993) Old Milton only to the north of this locality). Two sections of fluvial gravels were measured by imaging station (BAR11 S1 and S2) (Figure 5.12). Synthetic boreholes BAR SBH1 and SBH2 record sands and gravels in the Barton Cliff coastal section being around 3.4 m to 3.5 m in thickness. Bedrock contact height is around 26.6 m O.D. and 24.4 m O.D.

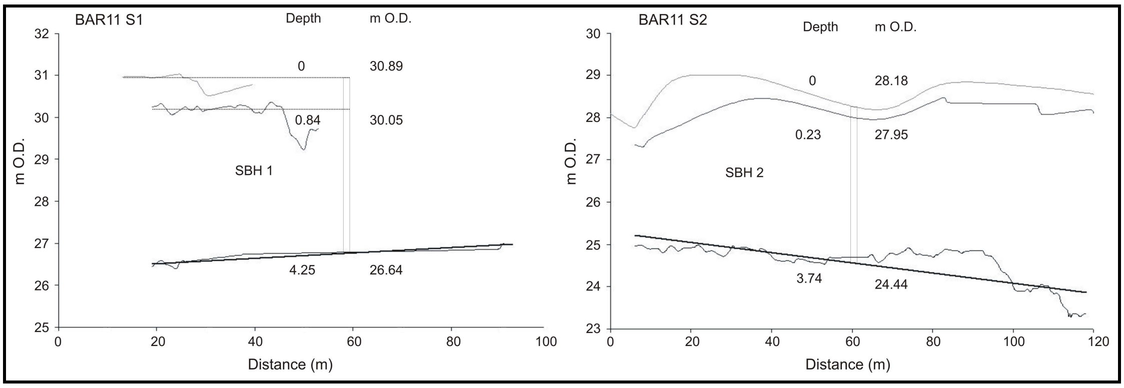


Figure 5.12. Bedrock height (with trend line), terrace surface height and ground level of coastal sections BAR11 S1 and S2 recorded at Barton Cliff (Barton on Sea). Synthetic borehole BAR SBH 1 and 2 locations and heights also shown. The terrace is attributed to Old Milton (Allen and Gibbard 1993)/ Becton Farm (Westaway *et al*. 2006).

Table 5.10. Synthetic borehole data from Imaging Station sections in Western Solent region 3. The current terrace attributions of Allen and Gibbard (1993) and Westaway *et al*. (2006) are shown.

Reference	Easting	Northing	Ground level (m O.D.)	Gravel thickness (m)	Bedrock height (m O.D.)	Terrace: Allen & Gibbard	Terrace: Westaway *et al.*
BAR SBH 1	424240	092887	30.89	3.41	26.64	Old Milton	Becton Farm
BAR SBH 2	424566	092799	28.18	3.51	24.44	Old Milton	Becton Farm
BAR SBH 4	425562	092543	26.79	3.12	22.66	Taddiford Farm	Downton
BAR SBH 5	425908	092427	24.65	4.08	20.39	Taddiford Farm	Downton
HOR SBH 1	426449	092209	23.62	4.02	19.11	Stanswood Bay	Stanswood Bay
HOR SBH 2	426387	092230	24.66	3.23	20.13	Stanswood Bay	Stanswood Bay
ROO SBH 1	428344	091562	12.03	2.03	9.60	Milford on Sea	Milford on Sea
ROO SBH 2	428257	091590	14.66	4.46	9.66	Milford on Sea	Milford on Sea

5.5 The borehole record of the Western Solent Region

An assessment was made of the available borehole record from terraces attributed to the Solent River in the Western Solent region (Allen and Gibbard 1993; Westaway *et al*. 2006) in order to determine each logs' inclusion in this study. Boreholes that were determined to contain sands and gravels of likely fluvial origin and provided location, ground level and bedrock contact data were included. The resulting dataset consists of 226 records (Table 5.11, Table 5.16, at end of chapter; Figure 5.13) that have been used in the construction of long profile projections as described in sections 5.6 and 5.7 below. The Western Solent region borehole record is concentrated in the Fawley area, while elsewhere coverage is spatially and stratigraphically even if sparse in the lowest terrace levels.

Table 5.11. Distribution of the 226 borehole records from the Western Solent region used in the study. Terrace attributions as mapped by Allen and Gibbard (1993) and Westaway *et al*. (2006). Terrace nomenclature: BF Becton Farm; BH Beaulieu Heath; DN Downton; HOR Hordle; HR Holmsley Ridge; LP Lepe; MP Mount Pleasant; MS Milford on Sea; OM Old Milton; PN Pennington; SB Stanswood Bay; RC Rook Cliff; SLF St Leonards Farm; SP Setley Plain; SW Sway; TF Taddiford Farm; TP Tiptoe; TD Tom's Down; WO Woolton.

Scheme	PN	SLF	LP	RC	MS	SB	HOR	TF	TD	DN	BF	OM	MP	SP	BH	TP	SW	HR	WO	Total
A. & G.	3	-	6	-	8	11	-	11	6	-	-	20	18	114	6	8	7	8	-	226
W. *et al.*	1	5	2	2	5	11	3	-	7	9	19	19	20	14	88	6	7	-	8	226

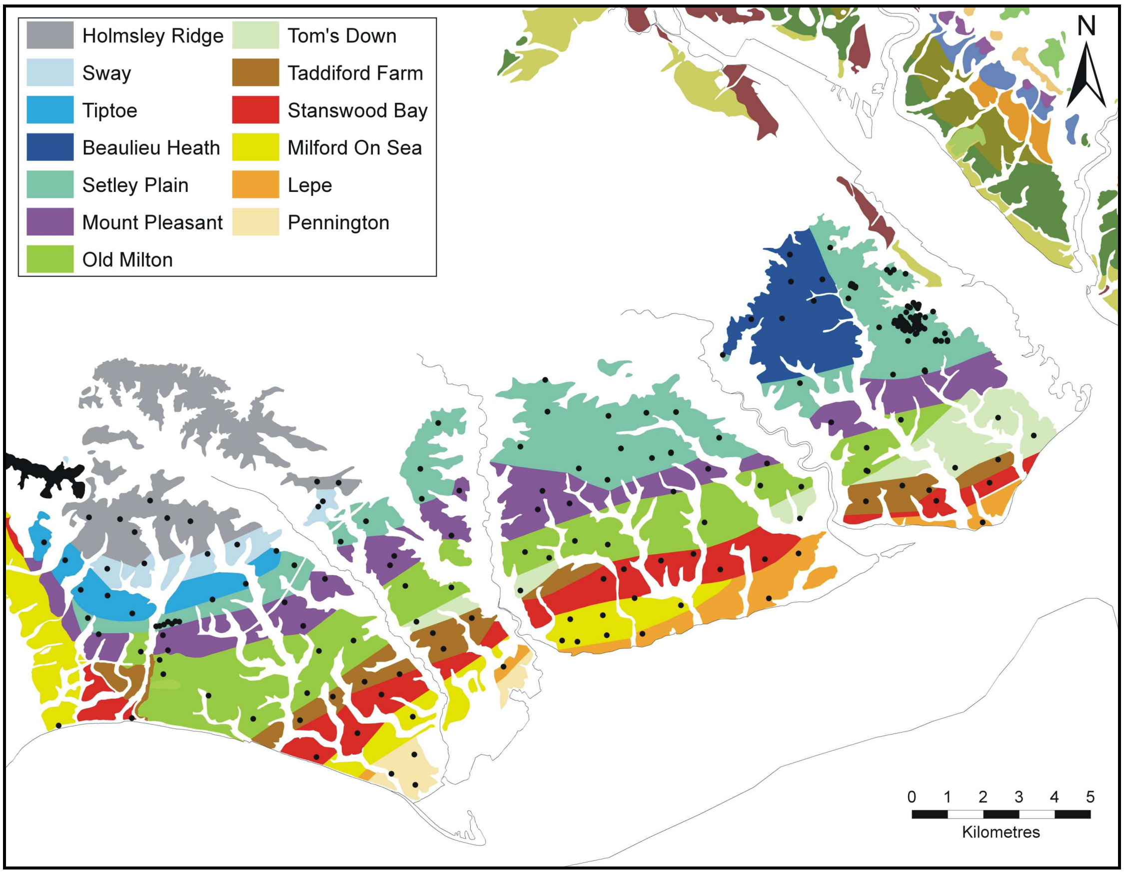


Figure 5.13. Location map of boreholes in the terraces of the Western Solent region (mapping scheme of Allen and Gibbard 1993).

5.6 The terraces of the Western Solent Region: the Allen and Gibbard (1993) and Westaway *et al.* (2006) schemes compared

The following section will describe and define the fluvial terraces of the Solent River as they extend across the Western Solent region. Terraces are presented using the nomenclature of Allen and Gibbard (1993) and Westaway *et al.* (2006). Fieldwork conducted in the Western Solent Region has produced a significant additional dataset for the majority of terraces in the study area, consisting of bedrock contact, ground level and (excluding GPR data) gravel thickness. The additional dataset for the Western Solent region consists of 46 synthetic borehole logs generated during fieldwork by this study (Table 5.13, at end of chapter), with 20 stratotype sites from Allen and Gibbard (1993) (Table 5.14, at end of chapter) and 4 PASHCC sites (Table 5.15, at end of chapter). Each borehole and fieldwork data log collected has been attributed to a terrace according to the schemes of Allen and Gibbard (1993) and Westaway *et al.* (2006) and used to construct long profile projections. These long profiles can be seen in Figures 5.14 and 5.15. When the additional borehole and fieldwork data are included in projections they reveal considerable variation in the altitudinal range and resulting gradient of a number of terraces as currently defined across the three regions of the Western Solent.

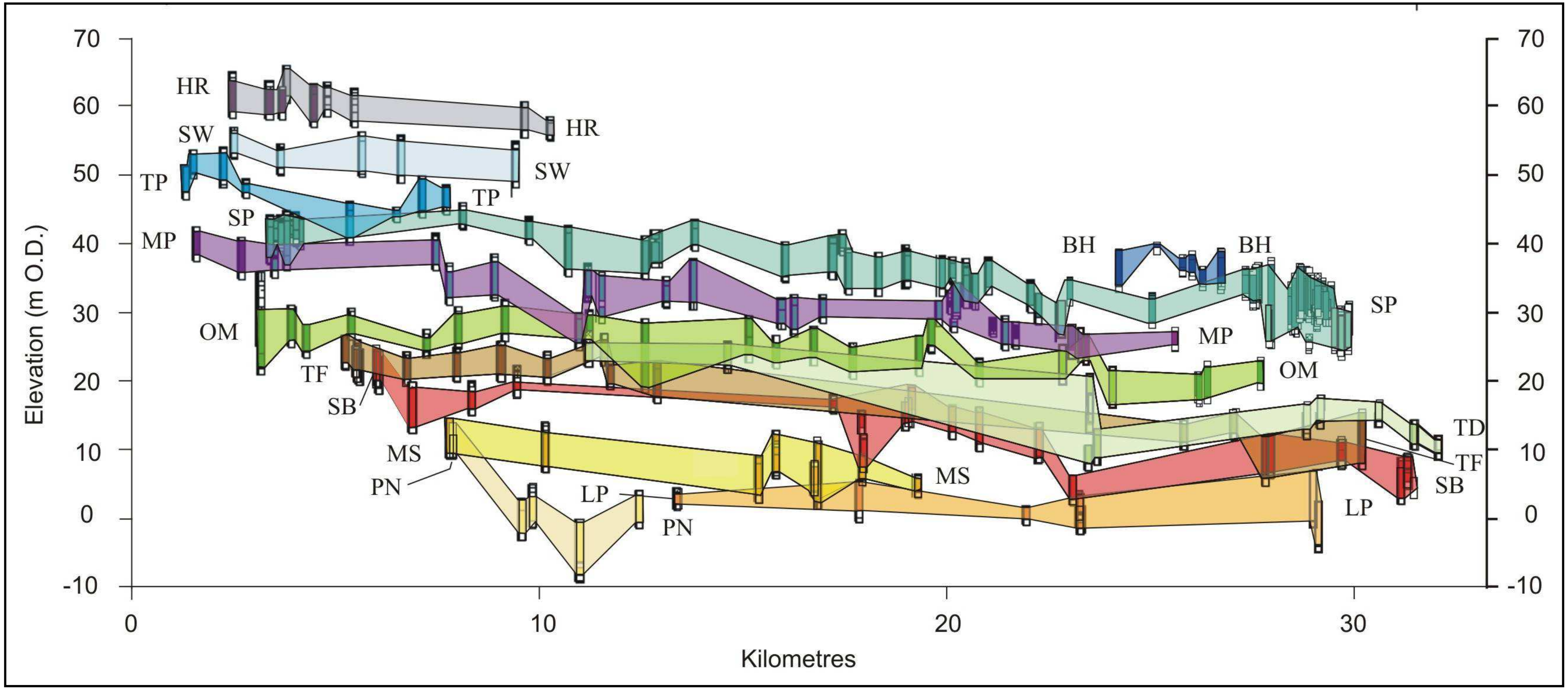


Figure 5.14. The terrace stratigraphy of the Solent River in the Western Solent region using borehole and fieldwork data collated during this study. Stratigraphic scheme is that of Allen and Gibbard (1993). Key: BH Beaulieu Heath; HR Holmsley Ridge; LP Lepe; MP Mount Pleasant; MS Milford on Sea; OM Old Milton; PN Pennington; SB Stanswood Bay; SP Setley Plain; SW Sway; TD Tom's Down; TF Taddiford Farm; TP Tiptoe. Profile projected along N70°E with distance measured from zero at SZ 20250 90397.

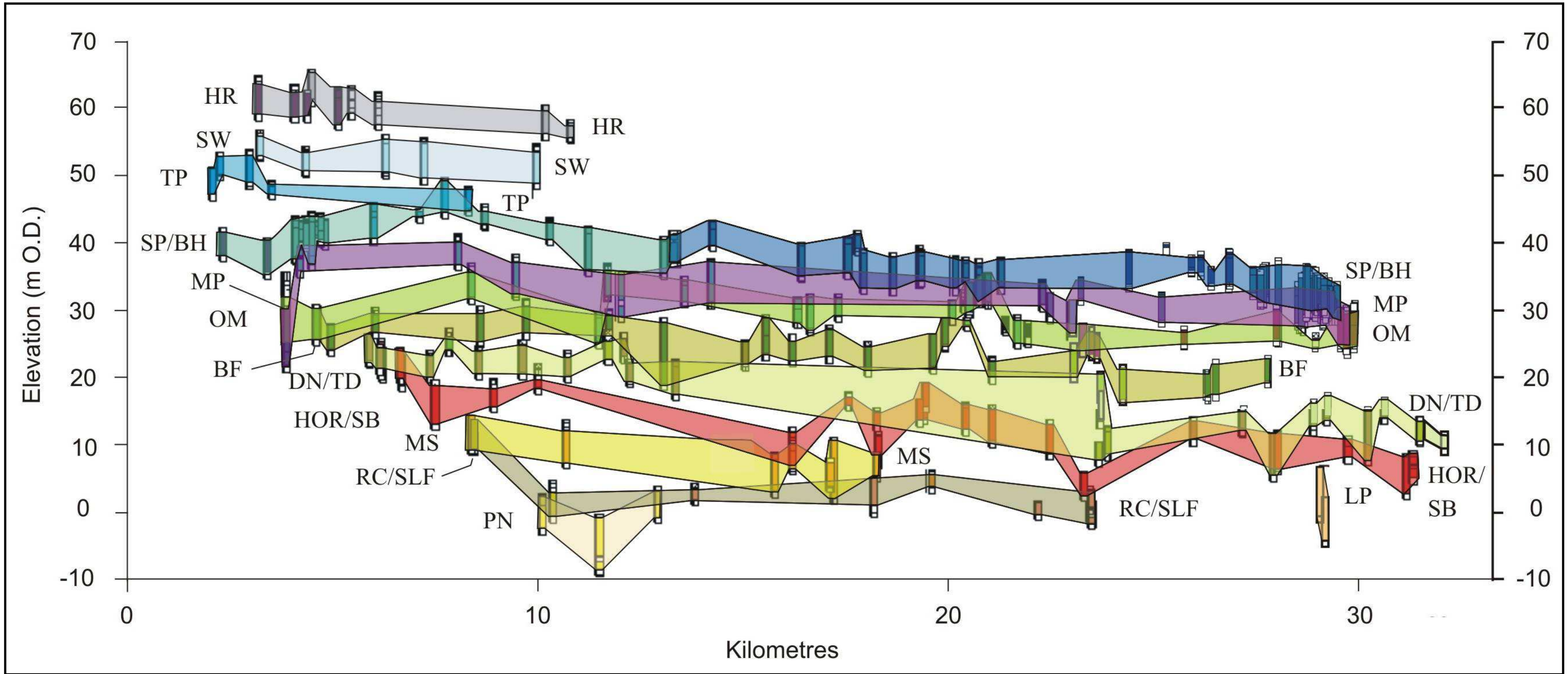


Figure 5.15. Terrace stratigraphy of the Solent River in the Western Solent region using borehole and fieldwork data collated during this study. Stratigraphic scheme is that of Westaway *et al*. (2006). Key: BF Becton Farm; BH Beaulieu Heath; DN Downton; HOR Hordle; HR Holmsley Ridge; LP Lepe; MP Mount Pleasant; MS Milford on Sea; OM Old Milton; PN Pennington; RC Rook Cliff; SLF St Leonards Farm; SB Stanswood Bay; SP Setley Plain; SW Sway; TD Tom’s Down; TP Tiptoe. Profile projected along N70°E with distance measured from zero at SZ 20250 90397.

Due to the application of different projection geometries it is not possible to produce a single model incorporating the terrace stratigraphies of Allen and Gibbard (1993) and Westaway *et al*. (2006) across the whole Western Solent region. As highlighted above (Tables 5.1, 5.5 and 5.9), the schemes correlate terrace bodies slightly differently in each part of the Solent (divided in this study into Regions 1, 2 and 3) resulting in three slightly different stratigraphic sequences. The terraces of the Western Solent are therefore described below in ascending altitudinal order, with comparison of terraces ascribed equivalent names in the nomenclature of each scheme. As far as possible this approach highlights a number of the discrepancies between the Allen and Gibbard (1993) and Westaway *et al*. (2006) schemes.

The lowest altitudinal terrace present in the sequence of both schemes is the Pennington terrace (Figure 5.16), a unit restricted in distribution to Region 3 between Christchurch Bay and the Lymington River. Borehole records are available from just five locations: to the west, at Knold (SZ29 SE11) and Keyhaven (SZ29 SW1), ground level is recorded at 5.00 m and 3.10 m O.D. with bedrock contact at -0.30 m and -2.10 m O.D. respectively, while Allen and Gibbard's (1993) Pennington stratotype locations record an upper gravel (PNU, ground level at around 4 m O.D. and bedrock contact at -0.50 m O.D.) and lower gravel (PNL, ground level at around 0 m O.D. and bedrock contact recorded at -6.20 m and -8.20 m O.D.). At Milford on Sea, borehole SZ29 SE45 indicates an apparent error in terrace attribution, recording ground level at 14.02 m O.D. and bedrock contact height at 6.40 m O.D. This level is more consistent with the Milford on Sea terrace as seen in nearby fieldwork sites ROO11 S1 and S2 (see Figure 5.19). Only the south-eastern extent of the terrace defined by Allen and Gibbard (1993) is included in the Pennington terrace of Westaway *et al*. (2006). The latter re-assign the northern extent of the terrace's distribution (including boreholes SZ29 SE11 and SZ29 SE45 noted above) to the Rook Cliff terrace.

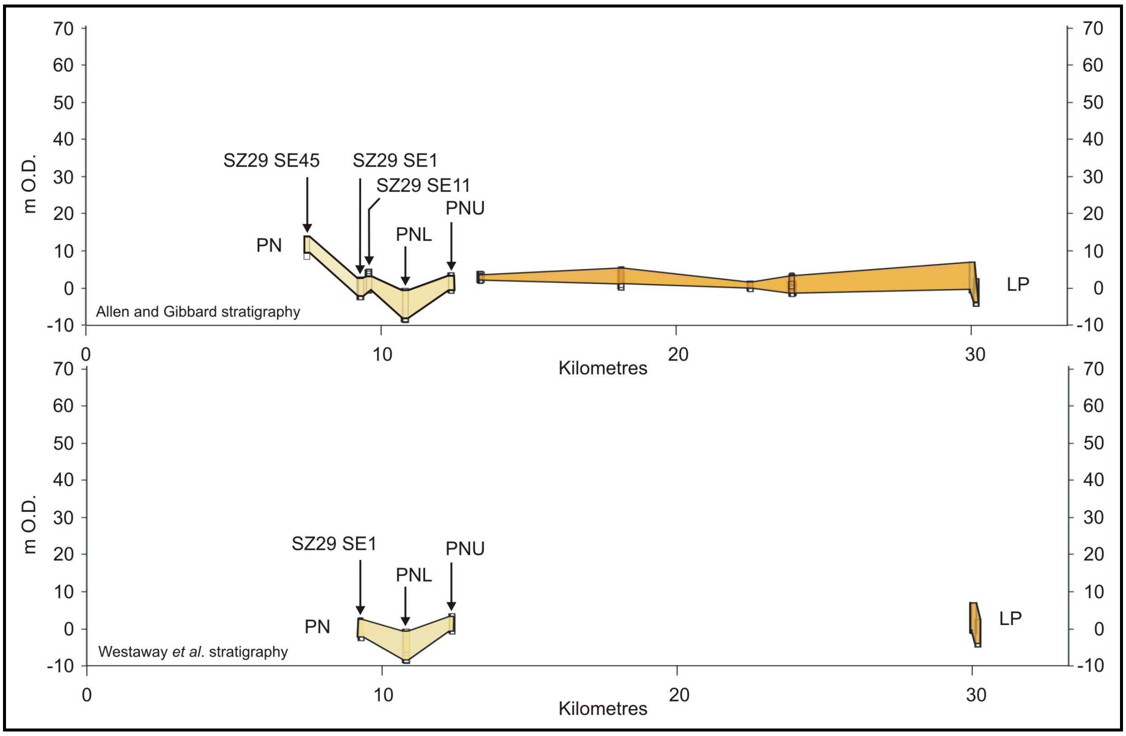


Figure 5.16. The long profile projection and distribution of data points in the Pennington terrace of Allen and Gibbard (1993) and Westaway *et al.* (2006). Lepe terrace included for comparison. Profile projected along N70°E with distance measured from zero at SZ 20250 90397.

The second altitudinal terrace in the sequence of both schemes is the Lepe terrace (Figure 5.17). Distribution of the Lepe terrace in the Westaway *et al.* (2006) scheme is again restricted, this time to Region 1. The terrace as recognised by Allen and Gibbard (1993) extends across all regions, but Westaway *et al.* (2006) attribute the Region 2 and 3 deposits to St Leonards Farm (see below). In the scheme of Allen and Gibbard (1993), the Lepe terrace is seen in borehole SZ39 SW4 with ground level at 4.50 m O.D. and bedrock contact at 2.20 m O.D. Boreholes SZ49 NE16 and NE17 are the furthest downstream records of the terrace, with ground level recorded at 7.10 m O.D. and 2.75 m O.D., and bedrock contact at -0.05 m O.D. and -3.80 m O.D., respectively. The mapping of Westaway *et al.* (2006) is only represented by the aforementioned boreholes SZ49 NE16 and NE17 and Allen and Gibbard's (1993) Lepe Upper Gravel stratotype (LPU); located nearby, the section recorded ground level at 6.00 m O.D. and bedrock contact at 1.90 m O.D.

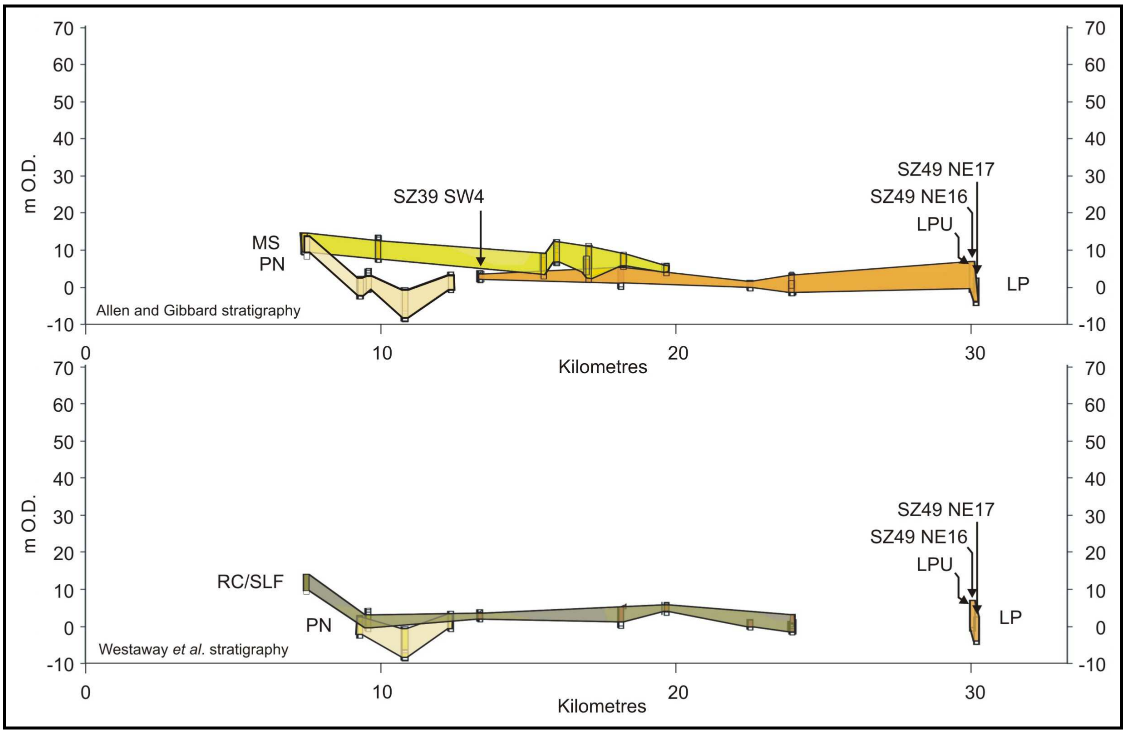


Figure 5.17. The long profile projection and distribution of data points in the Lepe terrace of Allen and Gibbard (1993) and Westaway *et al.* (2006). Terraces above and below included for comparison. Profile projected along N70°E with distance measured from zero at SZ 20250 90397.

The third terrace level in the Westaway *et al.* (2006) scheme, Rook Cliff/St Leonards Farm (Figure 5.18), has no direct equivalent in the Allen and Gibbard (1993) stratigraphy. As previously noted, the western extent of Allen and Gibbard's (1993) Pennington terrace is reassigned to Rook Cliff by Westaway *et al.* (2006), while much of the former's Lepe terrace is attributed to St Leonards Farm. To the west in Region 3 the terrace is seen in borehole SZ29 SE45 at Milford on Sea, with ground level recorded at 14.02 m O.D. with bedrock contact at 6.4 m O.D. The furthest record downstream is borehole SZ49 NW3 at St Leonards Farm, which records ground level at 3.7 m O.D. and bedrock at -1.3 m O.D. The nearby Lepe Lower Gravel (LPL) stratotype of Allen and Gibbard (1993), attributed to this terrace by Westaway *et al.* (2006), records ground level at 4.0 m O.D. with bedrock at -0.5m O.D.

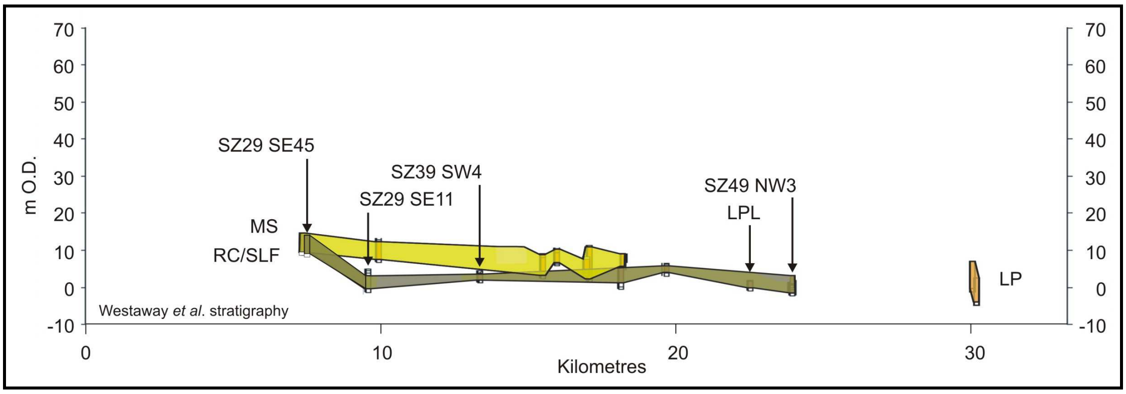


Figure 5.18. The long profile projection and distribution of data points in the Rook Cliff/St Leonards Farm terrace of Westaway *et al*. (2006). Terraces above and below included for comparison. Profile projected along N70°E with distance measured from zero at SZ 20250 90397.

The fourth terrace level in the Western Solent is ascribed to the Milford on Sea terrace in both schemes (Figure 5.19), with the distribution of the terrace largely similar through Regions 2 and 3, not appearing in Region 1. To the west, the terrace is exposed at Rook Cliff (Milford on Sea area) (SZ 283 915) where bedrock contact is ~9.6 m O.D. and ground level ranges from 12 m to 14.6 m O.D. (ROO SBH1 and S2). The furthest record downstream in the terrace in the scheme of Allen and Gibbard (1993) is borehole SZ39 NE12 at Boldre (SZ 3745 9638), where bedrock contact is at 4 m O.D. and ground level at 6.6 m O.D. The downstream extent in the Westaway *et al*. (2006) scheme is last seen in synthetic borehole WSOL23 9 (bedrock contact at 5.72 m O.D., ground level 9.1 m O.D.). The Milford on Sea terrace as defined by Westaway *et al*. (2006) is slightly less extensive from back to front, particularly in Region 2. Here, the northern extent of the terrace is attributed to Stanswood Bay, and to the south and east the terrace is incorporated into Westaway *et al*.'s (2006) St Leonards Farm terrace.

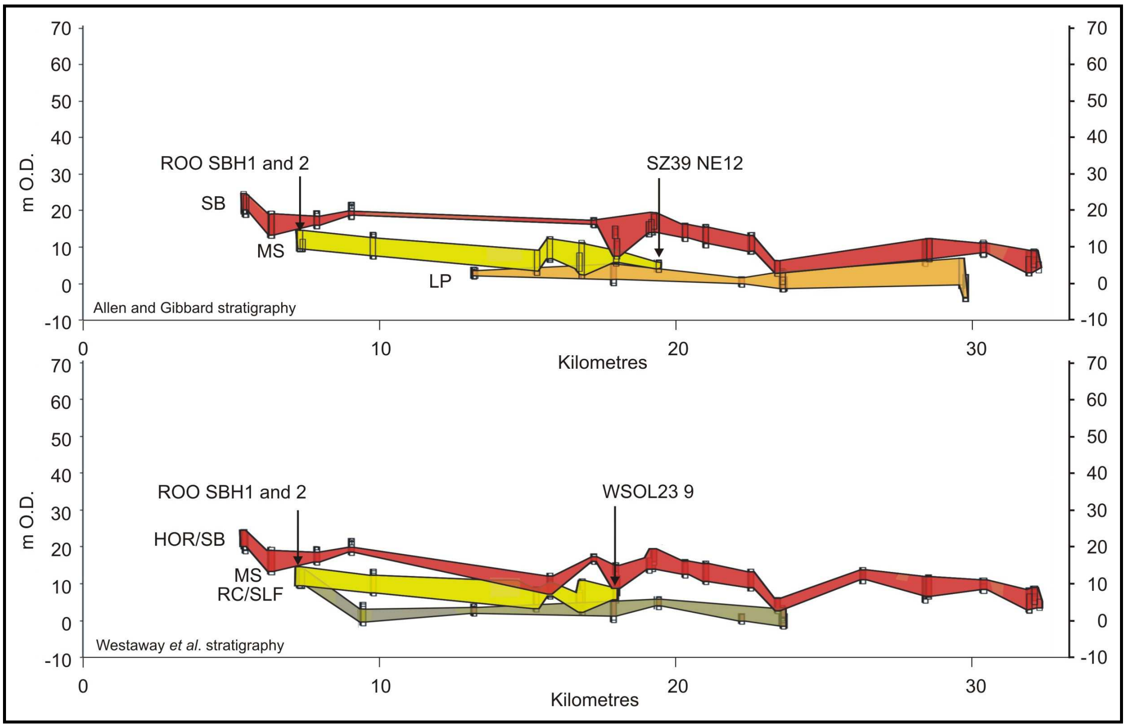


Figure 5.19. The long profile projection and distribution of data points in the Milford on Sea terrace of Allen and Gibbard (1993) and Westaway *et al.* (2006). Terraces above and below included for comparison. Profile projected along N70°E with distance measured from zero at SZ 20250 90397.

The fifth altitudinal terrace in the sequence of both schemes is the Stanswood Bay terrace (Figure 5.20), although in Region 3 this terrace level is referred to as the Hordle terrace in the scheme of Westaway *et al*. (2006). The Stanswood Bay terrace as defined Allen and Gibbard (1993) and Westaway *et al*. (2006) is more comparable in its distribution than any other terrace. It is recorded as a continuous unit from Christchurch Bay upstream in Region 3 to Stanswood Bay downstream in Region 1. Coastal exposures at Hordle Cliff (HORSZ 264 922) record bedrock contact at between 19.1 and 20.1 m O.D., with ground level at 23.6 to 24.6 m O.D. (HOR SBH 1 and 2 respectively). The furthest upstream borehole is SZ29 SE4 (ground level 19.9 m O.D., bedrock at 13.4 m O.D.), which appears low compared to the nearby coastal exposures. The mapping of Westaway *et al*. (2006) in Region 2 is slightly more extensive from back to front, where some of their Stanswood Bay terrace is attributed by Allen and Gibbard (1993) to Milford on Sea (as seen at boreholes SZ39 NW20 and SZ39 NE8). Similarly in Region 1, as discussed above, Allen and Gibbard's (1993) Taddiford Farm terrace is not recognised by Westaway *et al*. (2006) and the southern extent of that unit is attributed by the latter to Stanswood Bay. The downstream extent of the terrace is exposed in coastal sections at Stanswood Bay (SZ 473 004), where bedrock contact is recorded at between 4.01 m and 5.41 m O.D. with ground level up to around 9.4 m O.D. (STB SBH 1 to 4). The Allen and Gibbard (1993) stratotype location (SB), recorded towards the front edge of the terrace in the same coastal exposure, shows a similar ground level at 9 m O.D. Bedrock contact is recorded at 3.1 m O.D., which is slightly lower than the synthetic borehole data generated from the extensive sections surveyed during this study.

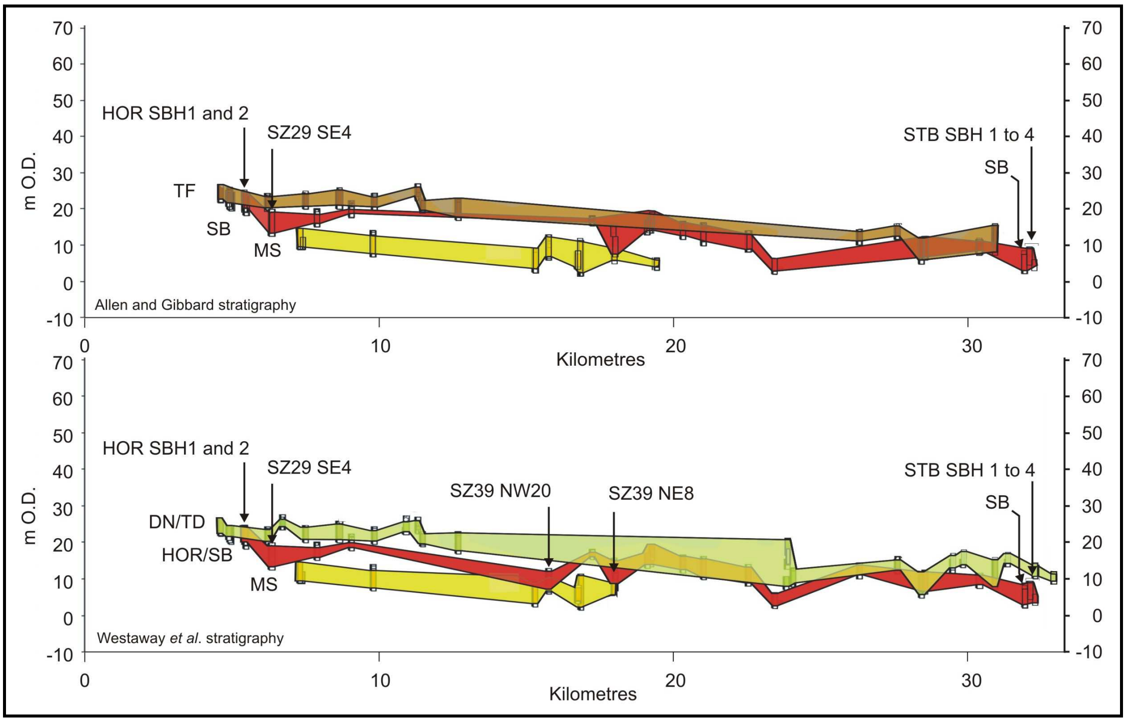


Figure 5.20. The long profile projection and distribution of data points in the Stanswood Bay terrace of Allen and Gibbard (1993) and the Hordle/Stanswood Bay terrace of Westaway *et al*. (2006). Terraces above and below included for comparison. Profile projected along N70°E with distance measured from zero at SZ 20250 90397.

The sixth altitudinal terrace level in the scheme of Allen and Gibbard (1993), Taddiford Farm (Figure 5.21), has no direct equivalent in the scheme of Westaway *et al*. (2006). The latter designate these gravel units downstream in the Western Solent as Tom’s Down, while upstream they are attributed to Downton. The Taddiford Farm terrace as defined by Allen and Gibbard (1993) is exposed at Barton Cliff (SZ 255 924), where bedrock contact is recorded at 20.39 and 22.6 m O.D. and ground level at 24.95 and 26.79 m O.D. (BAR SBH 5 and 4 respectively). The furthest downstream extent of the terrace is in the Fawley area, where borehole SU40 SE359 records bedrock contact at 8.1 m O.D. and ground level at 15.9 m O.D.

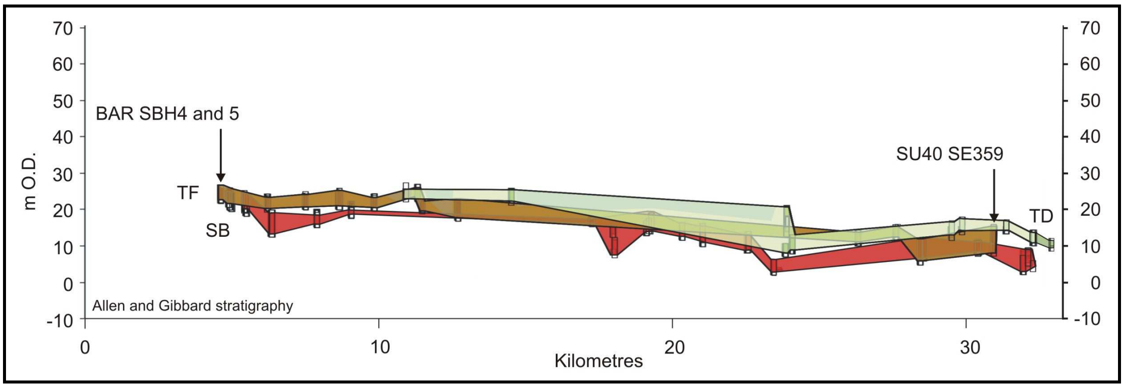


Figure 5.21. The long profile projection and distribution of data points in the Taddiford Farm terrace of Allen and Gibbard (1993). Terraces above and below included for comparison. Profile projected along N70°E with distance measured from zero at SZ 20250 90397.

The seventh altitudinal terrace level in both schemes is the Tom's Down terrace (Figure 5.22), although in Region 3 this terrace is referred to as Downton in the stratigraphy of Westaway *et al*. (2006). The Tom's Down terrace is extensive in Region 1 with a comparable distribution, except for the aforementioned Taddiford Farm unit of Allen and Gibbard (1993) which is incorporated in Tom's Down by Westaway *et al*. (2006). The terrace narrows considerably upstream, continuing into Region 2 as defined in both schemes. Further west in Region 2 Allen and Gibbard's (1993) Tom's Down terrace is equivalent to Westaway *et al*.'s (2006) Old Milton terrace. In Region 3 it forms part of Westaway *et al*.'s (2006) Downton terrace, which also incorporates a considerable portion of the Taddiford Farm terrace as described above. Allen and Gibbard's (1993) Tom's Down terrace is seen upstream in borehole SZ39 NW5 at Ramley, where ground level is at 27.3 m O.D. and bedrock contact 23 m O.D. Westaway *et al*.'s (2006) Downton terrace is exposed at Barton Cliff (SZ 255 925), in synthetic boreholes BAR SBH 4 and 5 discussed above. Both schemes record the downstream extent of the Tom's Down terrace as exposed in STB10 coastal sections 5 and 6 at Stanswood Bay (SZ 4778 0104). Here ground level is recorded at ~11.7 m O.D. and bedrock at 9.33 m O.D. and 9.78 m O.D. (STB SBH5 and 6 respectively).

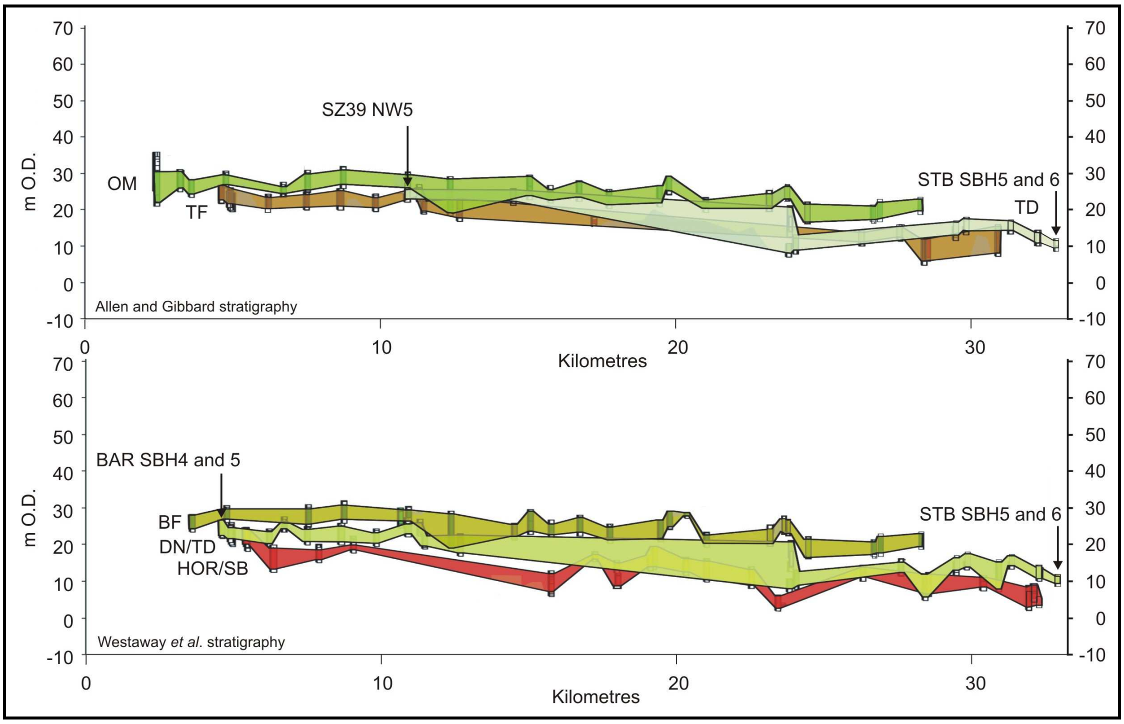


Figure 5.22. The long profile projection and distribution of data points in the Tom's Down terrace of Allen and Gibbard (1993) and the Downton/Tom's Down terrace of Westaway *et al*. (2006). Terraces above and below included for comparison. Profile projected along N70°E with distance measured from zero at SZ 20250 90397.

The eighth altitudinal terrace level in the scheme of Westaway *et al*. (2006), the Becton Farm terrace (Figure 5.23), has no direct equivalent in the scheme of Allen and Gibbard (1993). For the majority of its extent it is incorporated into the latter's Old Milton terrace as discussed below. Becton Farm is exposed at Barton Cliff (SZ 2424 9288) where bedrock is recorded in BAR SBH1 and 2 at 26.64 and 24.44 m O.D. respectively, with ground level at 30.89 and 28.18 m O.D. Downstream the terrace is seen in three boreholes in the Exbury area; SU40 SW146 (ground level at 21.35 m O.D., bedrock at 17.85 m O.D.), SU40 SW165 (ground level 22.8 m O.D. and bedrock 17.7 m O.D.), and SU40 SW147 (ground level 21.35 m O.D. and bedrock at 17.3 m O.D.). Further downstream borehole SU40 SW168 records ground level at 23.4 m O.D. and bedrock at 19.6 m O.D.

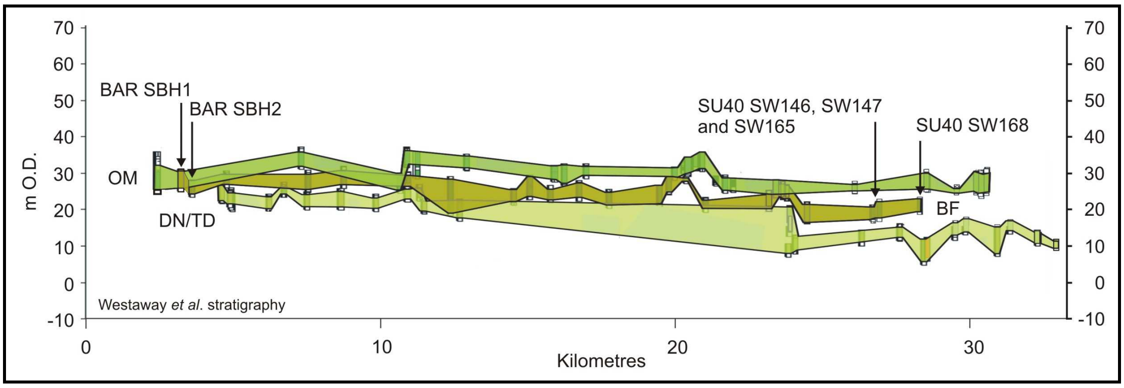


Figure 5.23. The long profile projection and distribution of data points in the Becton Farm terrace of Westaway *et al*. (2006). Terraces above and below included for comparison. Profile projected along N70°E with distance measured from zero at SZ 20250 90397.

The ninth altitudinal terrace in the Western Solent sequence, Old Milton (Figure 5.24), is recognised across the three regions in the scheme of both Allen and Gibbard (1993) and Westaway *et al*. (2006). However, as noted above, in Regions 1 and 2 the former's Old Milton terrace is included in the latter's Becton Farm terrace level. In Region 3 only the northern most distribution of the Old Milton terrace is agreed upon, representing around half of the terrace extent as defined by Allen and Gibbard (1993). The remainder of the unit is identified as Becton Farm by Westaway *et al*. (2006). In the scheme of Allen and Gibbard (1993) the upstream extent of the terrace is seen in boreholes SZ29 SW25 and 26, where ground level is at around 36 m O.D. and bedrock contact is recorded at around 26 m and 22 m O.D. respectively. Borehole SZ29 SW25 also represents the upstream extent of Westaway *et al*.'s (2006) Old Milton. The coastal sections BAR SBH1 and 2 discussed above are towards the front edge of Allen and Gibbard's (1993) Old Milton terrace. Downstream the terrace is seen in the three boreholes at Exbury mentioned in the previous section, SU40 SW146, SW147 and SW165, (recording ground level between 22.8 m O.D. and 21.35 m O.D. and bedrock between 17.3 m O.D. and 17.85 m O.D.) and SU40 SW168 (ground level 23.4 m O.D., bedrock 19.6 m O.D.). Westaway *et al*.'s (2006) Old Milton terrace extends further north in Region 3, correlating with parts of Allen and Gibbard's (1993) Mount Pleasant (e.g. at Hordle, borehole SZ29 NE8, ground level 37.2 m O.D. and bedrock 32.1 m O.D.), as it does downstream through Regions 2 and 1. Downstream at Fawley, the terrace is recorded in a group of boreholes (SU40 SW118, 119, 125 and 126) with ground level between 30.69 and 31.42 m O.D. and bedrock between 23.99 and 27.61 m O.D.

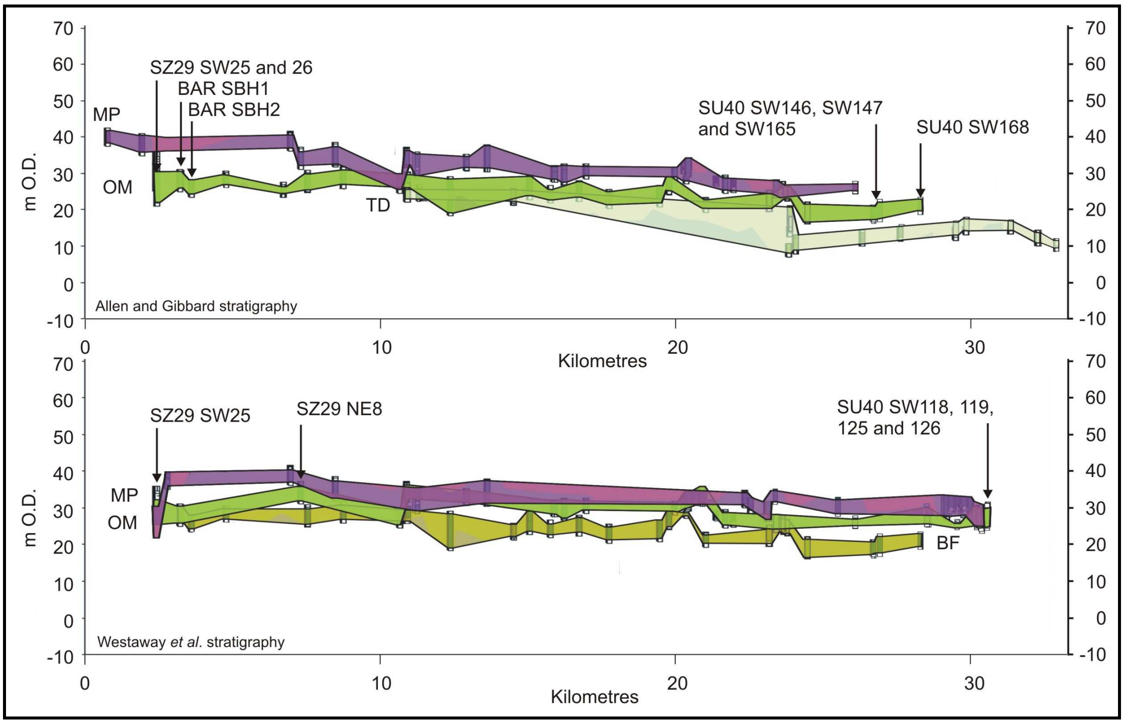


Figure 5.24. The long profile projection and distribution of data points in the Old Milton terrace of Allen and Gibbard (1993) and Westaway *et al*. (2006). Terraces above and below included for comparison. Profile projected along N70°E with distance measured from zero at SZ 20250 90397.

The tenth terrace level in the nomenclature of both schemes is the Mount Pleasant terrace (Figure 5.25). Distribution of the terrace across the Western Solent varies as identified by Allen and Gibbard (1993) and Westaway *et al*. (2006). The schemes largely agree in Region 3, although the map figure used by Westaway *et al*. (2006) does not extend as far upstream as that of Allen and Gibbard (1993) (see Figures 2.13 and 14). The furthest upstream borehole location agreed upon is SZ29 NW14 (ground level 42.5 m O.D., bedrock 36.4 m O.D.). Two boreholes just upstream near Hinton, SZ29 NW8 and NW13 (ground level 42.5 m O.D. and 41 m O.D., bedrock 38.5 m O.D. and 35.9 m O.D. respectively), appear to belong to Westaway *et al*.'s (2006) Setley Plain due to the orientation of the terraces here but SZ29 NW13 may actually fall into Mount Pleasant. These two boreholes represent the upstream extent of Allen and Gibbard's (1993) Mount Pleasant. The front edge of Westaway *et al*.'s (2006) Mount Pleasant terrace incorporates borehole SZ29 SW26 at New Milton discussed in the previous section. Allen and Gibbard (1993) map the downstream extent of the Mount Pleasant terrace as seen in borehole SU40 SW163, with ground level at 27.7 m O.D. and bedrock contact at 25.2 m O.D. According to the Westaway *et al*. (2006) scheme, the downstream projection of the terrace extends to a group of boreholes at Fawley. SU40 SW 130, SW129 and SW113, are the last records in the terrace, where ground level is ~30.5 m O.D. and bedrock ranges from 24.9 m O.D. to 27.9 m O.D. These elevations are comparable to those seen in the Old Milton terrace nearby as discussed in the previous section.

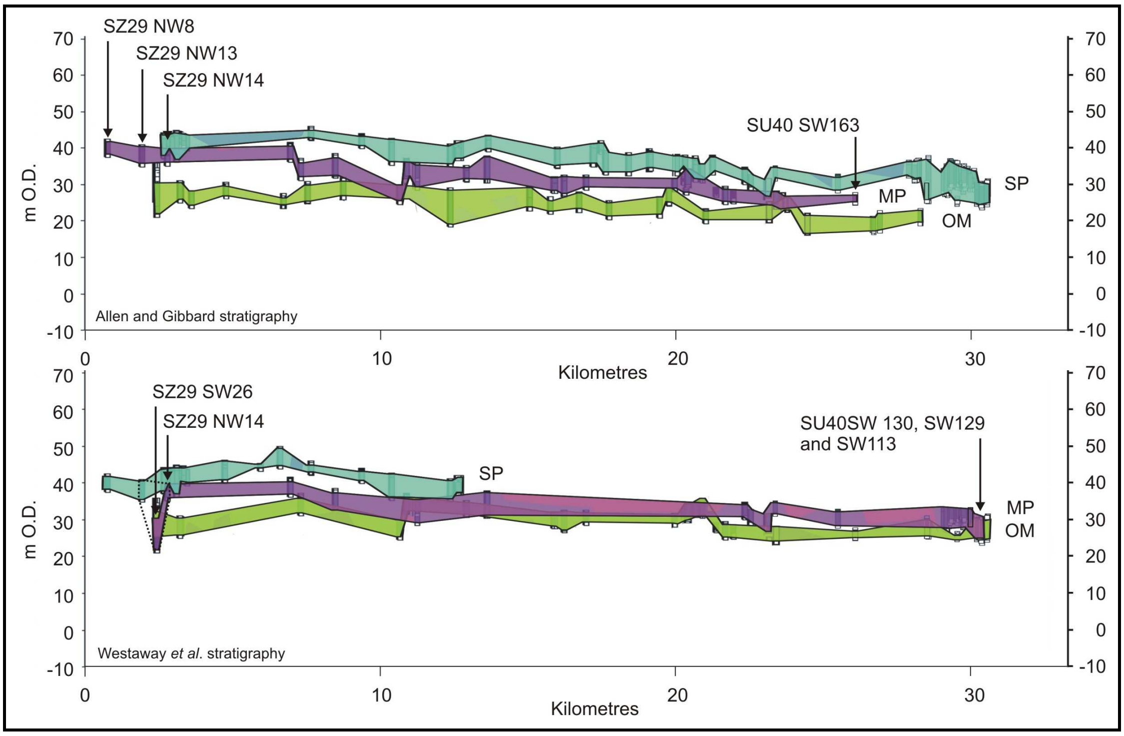


Figure 5.25. The long profile projection and distribution of data points in the Mount Pleasant terrace of Allen and Gibbard (1993) and Westaway *et al.* (2006). Terraces above and below included for comparison. Profile projected along N70°E with distance measured from zero at SZ 20250 90397.

The eleventh terrace in the sequence of the Western Solent stratigraphy is that of Setley Plain (Figure 5.26). The terrace only appears in Region 3 in the mapping of Westaway *et al*. (2006), while Allen and Gibbard (1993) trace the Setley Plain terrace across the region to Southampton Water. In Region 3 there is broad agreement on the terrace's upstream extent (though note discussion in previous section), with a group of six boreholes northwest of New Milton (SZ29 NW 56 to 61) recording ground level between 44.25 and 44.9 m O.D. and bedrock between 40.85 m and 37.1 m O.D. Westaway *et al*. (2006) only map the terrace as far downstream as Allen and Gibbard's (1993) stratotype on Setley Plain (SP) (SZ 3050 9940), where ground level is at 42 m O.D. and bedrock at 37.5 m O.D. Allen and Gibbard (1993) project the terrace further downstream to the Fawley area, where a range of ground level and bedrock elevations are seen in the 84 boreholes there. The previously discussed boreholes SU40 SW118, 119, 125 and 126, in Westaway *et al.*'s (2006) Old Milton terrace (ground level between 30.69 and 31.42 m O.D. and bedrock between 23.99 and 27.61 m O.D.), are the furthest downstream records.

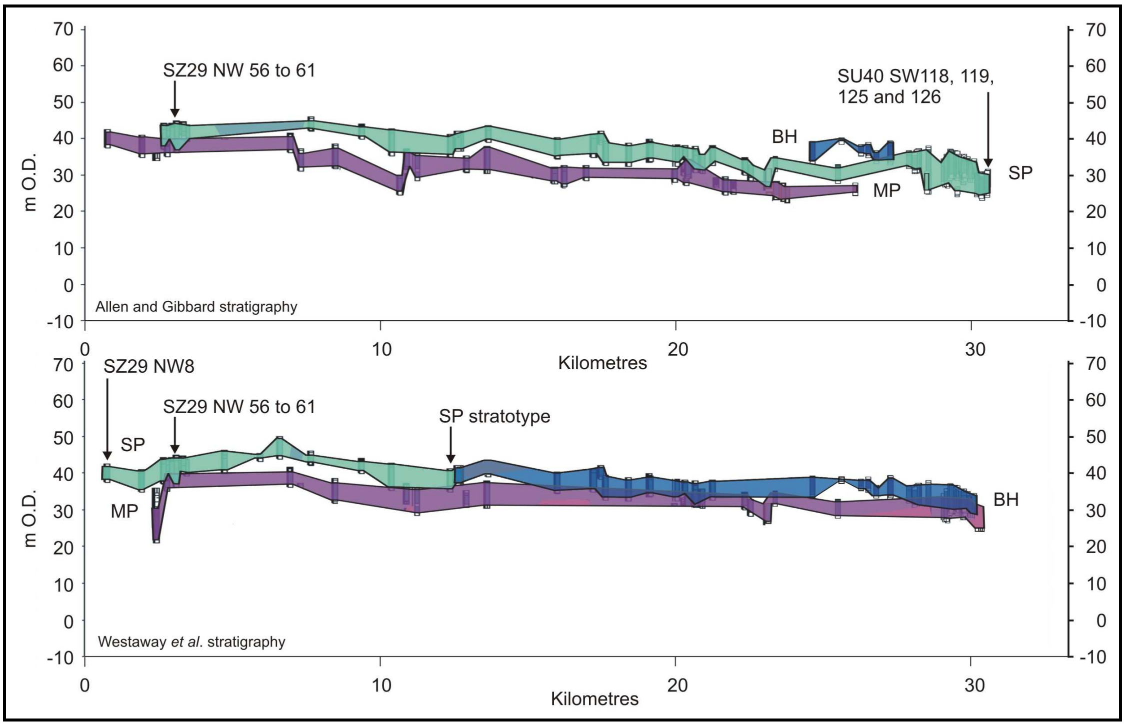


Figure 5.26. The long profile projection and distribution of data points in the Setley Plain terrace of Allen and Gibbard (1993) and Westaway *et al.* (2006). Terraces above and below included for comparison. Profile projected along N70°E with distance measured from zero at SZ 20250 90397.

The Beaulieu Heath terrace (Figure 5.27) is only recognised in Region 3 by Allen and Gibbard (1993), where it correlates with Westaway *et al*.'s (2006) Beaulieu Heath terrace only to the northwest. Here the former scheme records the terrace as seen in a group of seven boreholes from Dibden in the north to Beaulieu Heath. Ground level ranges between 36.4 m O.D. (borehole SU40 SW161) and 39.9 m O.D. (borehole SU40 SW158), with bedrock recorded at between 33.5 m O.D. (at Allen and Gibbard's (1993) Beaulieu Heath stratotype) to 39.1 m O.D. (borehole SU40 SW158). Westaway *et al*. (2006) project the terrace upstream to correlate with a gravel unit seen at Setley Plain south of Brockenhurst. Here boreholes SU30 SW4 and SW5 record ground level at 43.5 m and 42 m O.D. respectively, with bedrock at 39.9 m and 37.5 m O.D. Downstream the Westaway *et al*.'s (2006) Beaulieu Heath continues to a group of 54 boreholes towards the front of the terrace at Fawley. Ground level is as low as 30.63 m O.D. (borehole SU40 SW8) and bedrock 29.05 m O.D. (SU40 SW77).

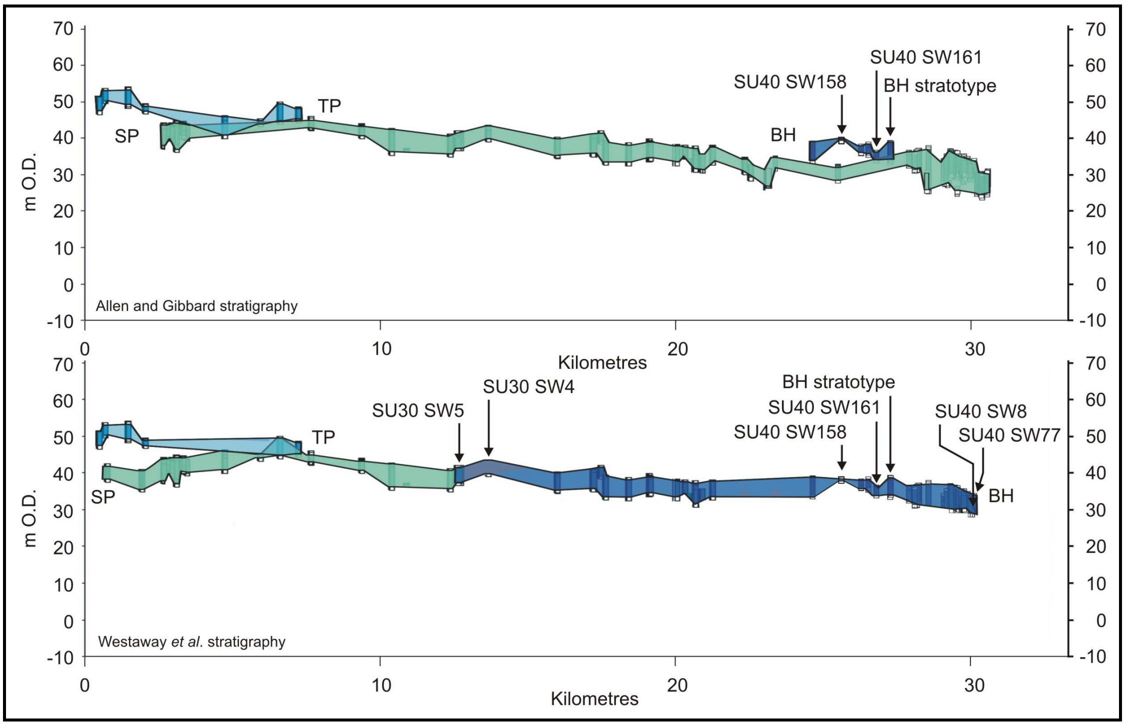


Figure 5.27. The long profile projection and distribution of data points in the Beaulieu Heath terrace of Allen and Gibbard (1993) and Westaway *et al*. (2006). Terraces above and below included for comparison. Profile projected along N70°E with distance measured from zero at SZ 20250 90397.

Of the three remaining terraces in the Western Solent stratigraphy (Figure 5.28), Tiptoe and Sway are largely agreed upon in the mapping schemes of Allen and Gibbard (1993) and Westaway *et al*. (2006). The highest terrace, Holmsley Ridge, is defined as the Wootton terrace in the latter scheme where borehole records were available. The only other major distinction between them is that the Westaway *et al*. (2006) scheme shows the Setley Plain terrace extending north to incorporate some of the Tiptoe terrace as defined in the Allen and Gibbard (1993) scheme. Distribution of the Tiptoe, Sway and Holmsley Ridge/Wootton terraces are restricted to the north of Region 3 of the Western Solent. The Tiptoe terrace is recorded with ground level at 51.1 m O.D. in borehole SZ19 NE20, with bedrock at 47.5 m O.D. The downstream extent is seen at borehole SZ29 NE4, where ground level is at 48.6 m O.D. and bedrock at 45.3 m O.D. The Sway terrace is seen in borehole SZ29 NW6 at North Hinton Farm, with ground level at 56.9 m O.D. and bedrock at 53.3 m O.D. The terrace extends downstream as far as Sway, where ground level is recorded at 54.7 m O.D. in borehole SZ29 NE11, with bedrock at 47.6 m O.D. The Holmsley Ridge/Wootton terrace is identified upstream in borehole SZ29 NW1, where ground level is at 65.1 m O.D. and bedrock 59.3 m O.D., and Blackhamsley Hill north of

Sway, where borehole SZ29 NE10 records ground level at 58.5 m O.D. and bedrock at 55.9 m O.D.

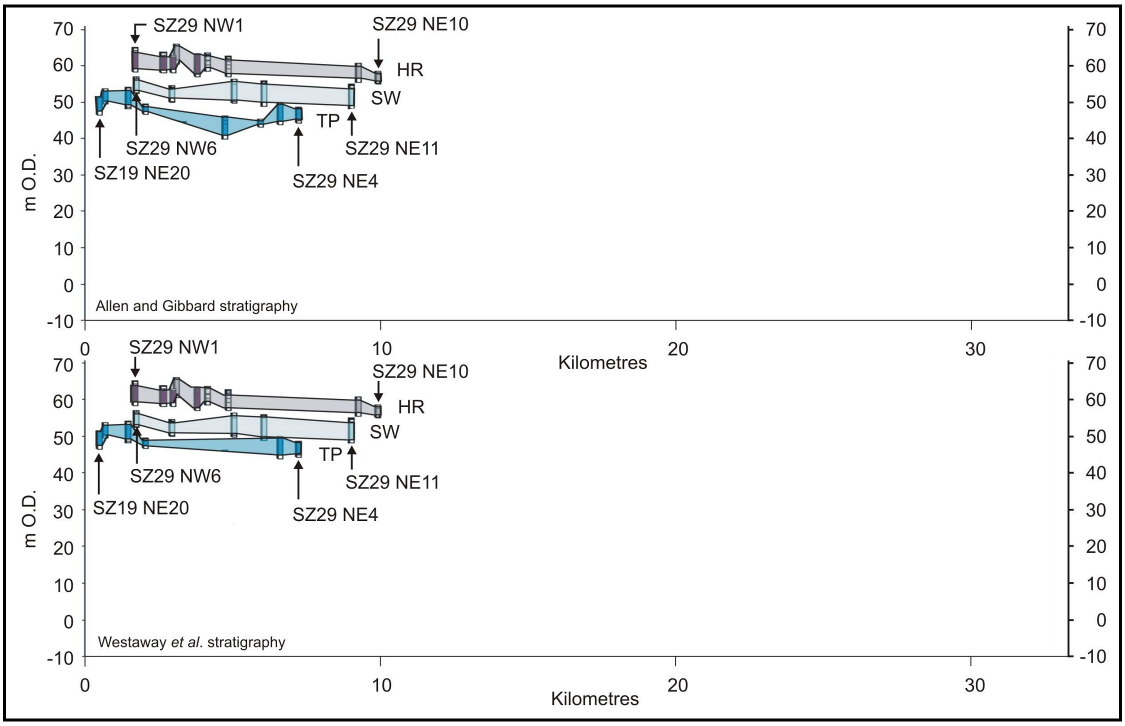


Figure 5.28. The long profile projection and distribution of data points in the Tiptoe, Sway and Holmsey Ridge/Wootton terraces of Allen and Gibbard (1993) and Westaway *et al*. (2006). Profile projected along N70°E with distance measured from zero at SZ 20250 90397.

5.7 Reassessing the terrace stratigraphy of the Western Solent Region

The Western Solent sequence is significant in that it links the archaeologically important Test Valley and Bournemouth regions. Projecting gradients upstream to the Bournemouth Solent and Stour and downstream to the River Test is fundamental to correlating the three areas. The above section highlights a number of significant differences between the Western Solent terrace schemes of Allen and Gibbard (1993) and Westaway *et al*. (2006). Importantly it also shows that there are stratigraphic issues evident within each of the schemes when additional data are applied to their terrace mapping. When projected using the expanded dataset of borehole records and fieldwork data collected here, both schemes lose clear stratigraphic division in some parts of their sequences. As highlighted when assessing the individual terrace units above, in many instances there appears to be little justification in distinguishing between terraces at particular locations. Therefore a reassessment of the terrace stratigraphy of the Western Solent was undertaken as set out in Chapter 3.6.

This section will describe the reattribution of borehole and fieldwork data that resulted from re-examining the terrace record of the Western Solent region, and outline the reasoning behind the changes made. Figure 5.29 shows the location of reassigned logs and the corresponding terrace mapping adjustments that resulted. Records that have been reassigned are numbered as in Table 5.12 and discussed in the relevant sections below. Terraces are described in the revised stratigraphy of this study, in the order that reassessment was undertaken. A revised long profile projection of the terrace stratigraphy of the Solent River is presented in Figure 5.30.

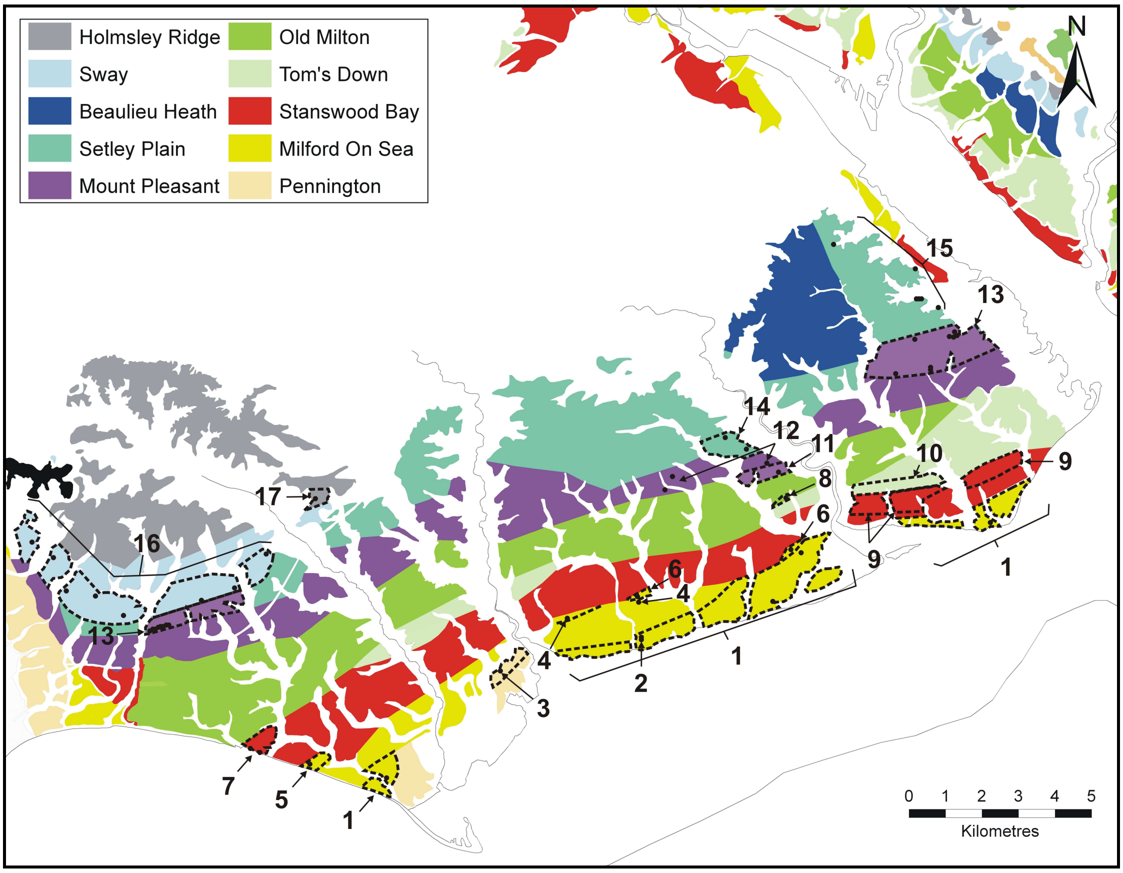


Figure 5.29. Mapping of the terrace stratigraphy of the Solent River in the Western Solent region as reassigned by this study (cf. Figure 5.1). Numbers show locations of borehole records and fieldwork data reassigned as in Table 5.12 and discussed in the appropriate sections below. Dashed lines show extent of mapping alterations.

Table 5.12. Adjustments made to terrace correlations and borehole data points in the Western Solent region record. Columns 3 and 4 show the mapping schemes of Allen and Gibbard (1993) and Westaway *et al.* (2006) respectively. Columns 5 and 6 show the revised attribution and rationale.

		Previous mapping			
Fig. Note	Reference	Allen and Gibbard	Westaway *et al.*	Revised terrace	Rationale
1	6 logs (see text)	Lepe/ Pennington	St Leonards Farm/ Lepe/ Rook Cliff	Milford on Sea	Milford on Sea extended downstream on altitudinal and gradient correlation
2	WSOL23 10	Lepe	St Leonards Farm	Milford on Sea	Altitudinally more consistent with Milford on Sea in the locality
3	SZ39SW4	Lepe	St Leonards Farm	Pennington	Altitudinally more consistent with Pennington in the locality
4	SZ39NE8, SZ39NW20	Milford on Sea	Stanswood Bay	Milford on Sea	Altitudinally more consistent with Milford on Sea in the locality
5	SZ29SE4	Stanswood Bay	Hordle	Milford on Sea	Altitudinally more consistent with Milford on Sea in the locality
6	WSOL21 8 WSOL23 8	Stanswood Bay	Stanswood Bay	Milford on Sea	Altitudinally more consistent with Milford on Sea in the locality
7	BAR11 S4 BAR11 S5	Taddiford Farm	Downton	Stanswood Bay	Altitudinally more consistent with Stanswood Bay in the locality
8	WSOL21 5	Old Milton	Becton Farm/ Tom's Down	Old Milton	Altitudinally more consistent with Old Milton in the locality
9	16 logs (see text)	Taddiford Farm/ Tom's Down	Downton/ Tom's Down	Stanswood Bay	Stanswood Bay extended downstream on altitudinal and gradient correlation
10	4 logs (see text)	Taddiford Farm/ Tom's Down	Becton Farm/ Downton/	Tom's Down	Tom's Down extended downstream on altitudinal and gradient correlation
11	WSOL21 4	Old Milton	Becton Farm	Mount Pleasant	Altitudinally more consistent with Mount Pleasant in the locality
12	WSOL21 3, WSOL23 2, WSOL23 3	Mount Pleasant	Old Milton	Mount Pleasant	Altitudinally more consistent with Mount Pleasant in the locality
13	33 logs (see text)	Setley Plain/ Mount Pleasant	Mount Pleasant/ Old Milton/ Setley Plain	Mount Pleasant	Mount Pleasant extended upstream and downstream on altitudinal and gradient correlation
14	WSOL21 1 WSOL21 2	Setley Plain	Mount Pleasant	Setley Plain	Altitudinally more consistent with Setley Plain in the locality
15	SU40NW47 & 62; SU40 SW4, 10, 11, 14 & 29	Setley Plain	Beaulieu Heath	Excluded	Altitudinally low for Setley Plain/ Beaulieu Heath, probably located on eroded terrace edge
16	12 logs (see text)	Tiptoe	Setley Plain/ Tiptoe	Setley Plain	Setley Plain extended upstream on altitudinal and gradient correlation
17	SZ29NE33	Sway	Sway	Holmsey Ridge	Altitudinally more consistent with Holmsey Ridge in the locality

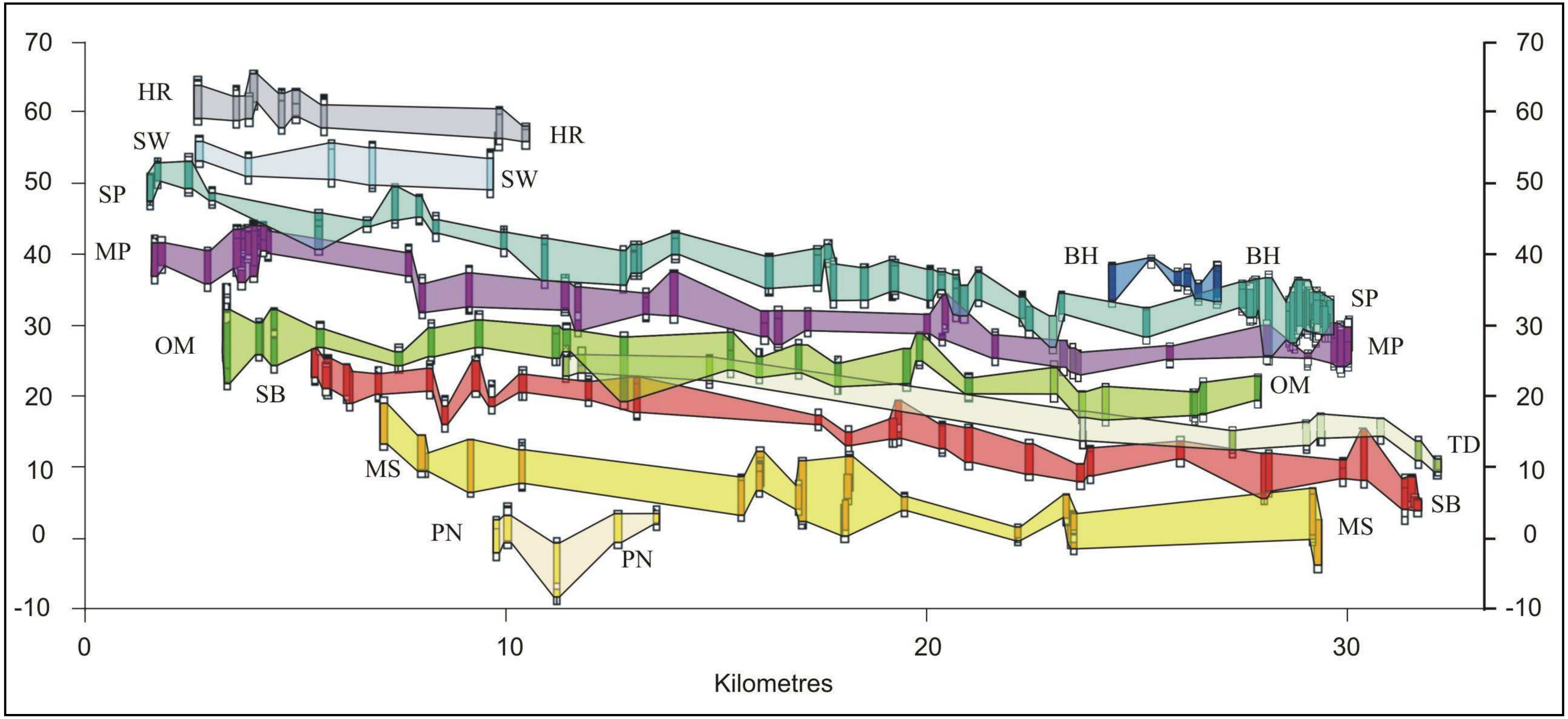


Figure 5.30. The terrace stratigraphy of the Solent River in the Western Solent region as assigned by this study. Terrace nomenclature: HR Holmsley Ridge; SW Sway; BH Beaulieu Heath; SP Setley Plain; MP Mount Pleasant; OM Old Milton; TD Tom's Down; SB Stanswood Bay; MS Milford on Sea; PN Pennington. Profile projected along N70°E with distance measured from zero at SZ 20250 90397.

In order to tackle the mapping issues discussed above, areas of agreed attribution of terrace extent were used to provide a foundation for re-interpretation. The agreement on the extent and gradient of the Stanswood Bay terrace as defined by Allen and Gibbard (1993) and Westaway *et al*. (2006) make it a useful benchmark from which analysis of terraces above and below it can be undertaken. Importantly, the terrace is continuous across region and is represented at both the upstream and downstream ends of the sequence. The Stanswood Bay terrace (Hordle in Westaway *et al*. 2006) is present in coastal exposures at Hordle Cliff in Christchurch Bay to the west and Stanswood Bay at the east end of the region. Therefore the gradient of the Stanswood Bay terrace is in agreement in both schemes. Westaway *et al*. (2006) project their Hordle/Stanswood Bay terrace at a gradient of 0.4 m km^{-1}, while Allen and Gibbard (1993) project a similar gradient of 0.44 m km^{-1}. The Stanswood Bay terrace, as described in both schemes, is therefore a key marker for a reassessment of the Western Solent terrace stratigraphy.

Stanswood Bay terrace

A re-evaluation of the Stanswood Bay terrace resulted in a number of logs being reassigned. Some data points in the Taddiford Farm and Tom’s Down terraces were found to occur at a height more consistent with the projection of the Stanswood Bay terrace, while others were re-assigned from the Stanswood Bay terrace to the lower Milford on Sea terrace on altitudinal grounds. At Hordle Cliff, borehole SZ29 SE4 (SZ 2724 9213) is located near the upstream end of the Milford on Sea terrace (Figure 5.29, note 5). The borehole’s bedrock elevation projects ~5.7 to 6.7 m below fieldwork sites HOR SBH 1 and 2 (see Figure 5.14) and has been reassigned to the Milford on Sea terrace (Figure 5.19). Downstream GPR SBHs WSOL21 8 (SZ 4051 9799) and WSOL23 8 (SZ 3612 9663) (Figure 5.29, note 6) record ground level and bedrock height more consistent with a continuation of the Milford on Sea terrace. The records are accordingly reattributed in the revised long profile (Figure 5.30) and the Milford on Sea terrace is extended downstream.

Further fieldwork carried out at locations in the Barton and Hordle Cliffs (between Barton on Sea and Milford on Sea, Western Solent Region 3, section 5.4 above) indicated little differentiation between the Stanswood Bay terrace and the next highest terrace; that of Taddiford Farm (Allen and Gibbard 1993)/ Downton (Westaway *et al*. 2006) (Figure 5.29, note 7). Synthetic boreholes BAR SBH 4 & 5 and the aforementioned HOR SBH 1 & 2 show minor altitudinal difference in either ground level (m O.D.) or bedrock contact (m O.D.) (Figure 5.31). The difference could reflect the variation in elevation between the back and front of the Stanswood Bay terrace and not two terrace levels as mapped by Allen and Gibbard (1993) and Westaway *et al*. (2006). There would appear to be no justification of such a division based on coastal exposures, and the more parsimonious approach taken here is to include them in the same Stanswood Bay terrace.

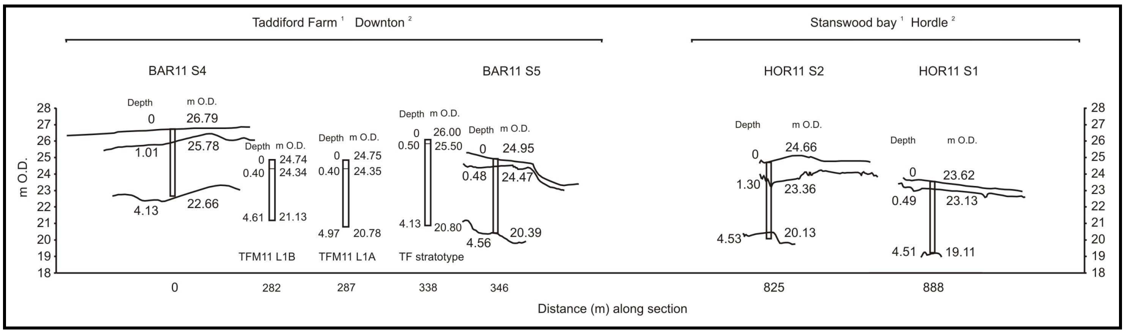


Figure 5.31. Coastal section in Barton Cliff and Hordle Cliff. Distance of each log along the coastal section is noted. [1] Allen and Gibbard (1993); [2] Westaway *et al*. (2006).

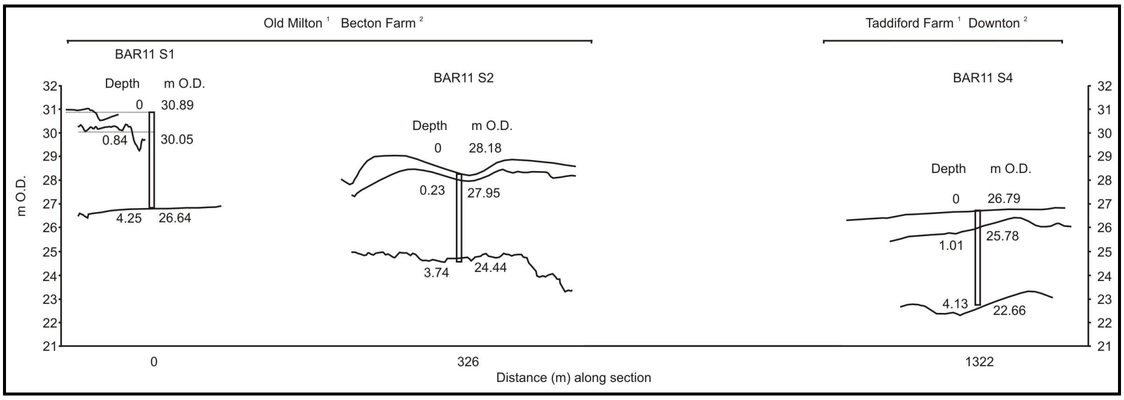


Figure 5.32. Coastal section in Barton Cliff between Barton on Sea and Hordle Cliff. Distance of each log along the coastal section is noted. Mapping schemes: [1] Allen and Gibbard (1993); [2] Westaway *et al*. (2006).

When the sections in Barton and Hordle Cliffs are examined in context with nearby borehole records in the long profile projection of the Western Solent (Figure 5.30) there appears to be no justification in differentiating the four terrace levels of Allen and Gibbard (1993) (Figure 5.14) or five terrace levels of Westaway *et al*. (2006) (Figure 5.15) between Barton on Sea and Milford on Sea. Three are recognised here: Milford on Sea, Stanswood Bay and Old Milton in ascending order. Coastal section recording at Barton on Sea (Figure 5.32) recorded ~200 m of the Old Milton terrace. It would appear to indicate that section BAR11 S4 is either the back edge of the Stanswood Bay terrace or the front edge of Old Milton. It is possible that a poorly defined intermediate terrace is present (which would correspond with the Tom's Down terrace downstream), but current evidence cannot state that conclusively (Figure 5.30).

Milford on Sea and Pennington terraces

In the terrace stratigraphy below Stanswood Bay Allen and Gibbard (1993) identify three terraces (Milford on Sea, Pennington and Lepe) and Westaway *et al*. (2006) four (Milford on Sea, Rook Cliff/St Leonards Farm, Pennington and Lepe). It was found that the majority of data points could be incorporated within one terrace from Milford on Sea to Allen and Gibbard's (1993) Lepe stratotype location based on gradient projection downstream (Figure 5.30). Boreholes SZ29 SE45, SZ39 NE9 and 17, SZ49 NE 16 and 17, SZ49 NW3 and Allen and Gibbard's (1993) Lepe Upper and Lower Gravels are reattributed to the Milford on Sea terrace (Figure 5.29, note 1). GPR SBH WSOL23 8 (SZ 3639 9556) was also found to altitudinally fit the Milford on Sea terrace (Figure 5.29, note 2). Five remaining records indicate a further, lower terrace comprising of gravels in the Pennington area. Borehole SZ39 SW4 is reattributed from Lepe to Pennington as it is close to the mapped downstream edge of the Pennington terrace and projects altitudinally below the revised Milford on Sea terrace (Figure 5.29, note 3). Boreholes SZ39 NE8 and 20 were found to be attributable to the Milford on Sea terrace (as in Allen and Gibbard (1993)) (Figure 5.29, note 4). It may be the case that the Milford on Sea terrace is a composite of two poorly separated terraces, with a lower level above the Pennington terrace. Downstream of Pennington there would appear to be a greater thickness to the Milford on Sea terrace than elsewhere in the sequence (Figure 5.30), but it is not possible to differentiate on current data.

Tom's Down terrace

A number of revisions were made to the terrace stratigraphy above the Stanswood Bay terrace. The downstream end of the sequence does appear to show the presence of a distinct Tom's Down terrace, restricted in extent to Region 3 (which may then relate to the three boreholes that fall between the Stanswood Bay and Old Milton terraces in a small terrace either side of the Lymington River). GPR SBH WSOL21 5 (SZ 4037 9948) was considered more consistent with the Old Milton terrace nearby (Figure 5.29, note 8). A group of 16 logs were included in the downstream end of the Stanswood Bay terrace as they fitted within the long profile projection (Figure 5.29, note 9), as did four further logs with the Tom's Down terrace (Figure 5.29, note 10). The latter two groups are split between three terraces in Westaway *et al*.'s (2006) scheme (Tom's Down, Downton and Becton Farm) and two terraces in Allen and Gibbard's (1993) as their profile orientations differ. The upstream Taddiford Farm/Downton terrace was largely reassigned, with no clear indication of a terrace level between Stanswood Bay and Old Milton in the west of the region (Figure 5.30).

Old Milton and Mount Pleasant terraces

Overall the Old Milton terrace largely agreed with the mapping of Allen and Gibbard (1993), with minor adjustments, and less so with Westaway *et al*.'s (2006) Becton Farm/Downton terraces. GPR SBH WSOL21 3 projects to the Mount Pleasant terrace (Figure 5.29, note 11), as do WSOL21 2 and WSOL23 2 and 3 (Figure 5.29, note 12). The Mount Pleasant terrace was also reassessed upstream to include a group of closely spaced boreholes that had previously been assigned to Setley Plain but which did not easily fit with an upstream projection of the terrace (Figure 5.29, note 13). Overall the Mount Pleasant terrace (Figure 5.30) was found to be slightly broader from its back edge to the front, with 30 boreholes reattributed to it from the Allen and Gibbard (1993) and/or Westaway *et al*. (2006) schemes (see Table 5.16).

GPR SBHs WSOL21 1 and 2 were found to be altitudinally more consistent with the Setley Plain terrace, as in Allen and Gibbard (1993) rather than Mount Pleasant (Westaway *et al*. (2006) (Figure 5.29, note 14). A number of boreholes in the Fawley area were found to project below the Setley Plain (Allen and Gibbard 1993)/Beaulieu Heath terrace (Westaway *et al*. 2006) due to their location on an eroded terrace edge and were therefore excluded from the revised long profile projection (Figure 5.29, note 15). Borehole records that had been identified as Tiptoe deposits also project onto the newly configured Setley Plain terrace. (Figure 5.29, note 16)

Beaulieu Heath, Sway and Holmsley Ridge/Wootton terraces

The remaining terrace levels identified are those of Beaulieu Heath, which is limited in distribution to the east of the region, and Sway seen only in the west. The latter may project downstream into the former, although a distinct nomenclature is maintained due to the distance separating the terrace bodies. The correlation of Setley Plain/Beaulieu Heath of Westaway *et al*. (2006) is not adopted here. Finally, the Holmsley Ridge/Wootton terrace is largely maintained as currently recognised by both Allen and Gibbard (1993) and Westaway *et al.*'s (2006). Borehole SZ29 NE33 was reattributed from Sway to Holmsey Ridge/Wootton (Figure 5.29, note 17).

The most parsimonious solution to the issues encountered with current stratigraphic models of the Western Solent terrace sequence would appear to be that shown in Figure 5.30. This scheme removes many of the inconsistencies of previous models which frequently saw terrace levels overlap as they projected downstream. Correlation of the revised terrace stratigraphy of the Western Solent with the River Test and Bournemouth regions (Chapters 4 and 6 respectively) is assessed in Chapter 8. The correlations proposed will be based on the upstream and downstream projection of gradients for the Western Solent terrace stratigraphy presented here.

Table 5.13. Synthetic borehole logs and fieldwork data in the Western Solent generated by this study.

Reference	Easting	North.	GL	Gr Th.	Bd Ht	Previous mapping: Allen and Gibbard 1993	Previous mapping: Westaway *et al*. 2006	Revised terrace scheme
BAR SBH 1	424240	092887	30.89	3.41	26.64	Old Milton	Becton Farm	Old Milton
BAR SBH 2	424566	092799	28.18	3.51	24.44	Old Milton	Becton Farm	Old Milton
BAR SBH 4	425562	092543	26.79	3.12	22.66	Taddiford Farm	Downton	Stanswood Bay
BAR SBH 5	425908	092427	24.65	4.08	20.39	Taddiford Farm	Downton	Stanswood Bay
HOR SBH 1	426449	092209	23.62	4.02	19.11	Stanswood Bay	Stanswood Bay	Stanswood Bay
HOR SBH 2	426387	092230	24.66	3.23	20.13	Stanswood Bay	Stanswood Bay	Stanswood Bay
MOS11 L1	428171	091619	-	-	-	Milford on Sea	Milford on Sea	Milford on Sea
ROO SBH 1	428344	091562	12.03	2.03	9.60	Milford on Sea	Milford on Sea	Milford on Sea
ROO SBH 2	428257	091590	14.66	4.46	9.66	Milford on Sea	Milford on Sea	Milford on Sea

Reference	Easting	North.	GL	Gr Th.	Bd Ht	Previous mapping: Allen and Gibbard 1993	Westaway *et al*. 2006	Revised terrace scheme
STB10 L1	447388	100486	9.38	3.53	5.41	Stanswood Bay	Stanswood Bay	Stanswood Bay
STB10 L5	447807	101029	10.52	0.78	9.54	Tom's Down	Tom's Down	Tom's Down
STB SBH 1	447388	100486	9.03	3.53	5.28	Stanswood Bay	Stanswood Bay	Stanswood Bay
STB SBH 2	447398	100595	7.21	2.92	4.12	Stanswood Bay	Stanswood Bay	Stanswood Bay
STB SBH 3	447406	100665	6.37	1.50	4.38	Stanswood Bay	Stanswood Bay	Stanswood Bay
STB SBH 4	447451	100702	5.66	1.37	4.01	Stanswood Bay	Stanswood Bay	Stanswood Bay
STB SBH 5	447780	101042	11.72	2.01	9.33	Tom's Down	Tom's Down	Tom's Down
STB SBH 6	447807	101029	11.62	1.36	9.78	Tom's Down	Tom's Down	Tom's Down
STB11 L1A	426702	92139	-	-	-	Stanswood Bay	Stanswood Bay	Stanswood Bay
STB11 L1B	426700	92139	-	-	-	Stanswood Bay	Stanswood Bay	Stanswood Bay
STB11 L2	426392	92239	-	-	-	Stanswood Bay	Stanswood Bay	Stanswood Bay
TFM11 L1A	425848	092450	24.75	3.57	20.78	Taddiford Farm	Downton	Stanswood Bay
TFM11 L1B	425843	092452	24.74	3.21	21.13	Taddiford Farm	Downton	Stanswood Bay
WSOL11 1	445145	100030	16.05	3.10	12.95	Tom's Down	Tom's Down	Tom's Down
WSOL11 2	445491	099703	9.81	3.23	6.58	Stanswood Bay	Stanswood Bay	Stanswood Bay
WSOL11 3	445774	098715	4.47	3.08	1.39	Lepe	Lepe	Lepe
WSOL12 1	443265	100409	21.20	3.25	17.95	Old Milton	Becton Farm	Becton Farm
WSOL12 2	444190	099875	14.86	2.81	12.05	Taddiford Farm	Tom's Down	Tom's Down
WSOL12 3	444692	099170	10.19	2.90	7.29	Stanswood Bay	Stanswood Bay	Stanswood Bay
WSOL12 4	444927	098715	3.76	2.45	1.31	Lepe	Lepe	Lepe
WSOL21 1	438677	101056	32.83	3.58	29.25	Setley Plain	Mount Pleasant	Setley Plain
WSOL21 2	439271	100810	31.55	4.65	26.9	Setley Plain	Mount Pleasant	Setley Plain
WSOL21 3	439673	100324	28.01	3.81	24.20	Mount Pleasant	Old Milton	Mount Pleasant
WSOL21 4	440099	100092	26.44	3.38	23.06	Old Milton	Becton Farm	Mount Pleasant
WSOL21 5	440372	099484	20.79	3.55	17.24	Old Milton or Tom's Down	Becton Farm or Tom's Down	Old Milton
WSOL21 6	440495	099166	18.01	4.28	13.73	Tom's Down	Tom's Down	Tom's Down
WSOL21 7	440561	098830	10.64	2.67	7.97	Tom's Down	Tom's Down	Stanswood Bay
WSOL21 8	440510	097993	6.18	3.33	2.85	Stanswood Bay	Stanswood Bay	Milford on Sea

Reference	Easting	North.	GL	Gr Th.	Bd Ht	Previous mapping: Allen and Gibbard 1993	Previous mapping: Westaway *et al.* 2006	Revised terrace scheme
WSOL22 1	435764	100173	39.13	4.42	34.71	Setley Plain	Beaulieu Heath	Beaulieu Heath
WSOL22 2	435380	099751	38.60	4.55	34.05	Setley Plain	Mount Pleasant	Mount Pleasant
WSOL22 3	435212	099328	30.50	3.70	26.80	Mount Pleasant	Old Milton	Old Milton
WSOL22 4	434815	098498	28.35	4.10	24.25	Old Milton	Becton Farm	Becton Farm
WSOL22 5	434357	098050	27.22	4.99	22.23	Old Milton	Becton Farm	Becton Farm
WSOL23 1	437407	100519	35.75	4.32	31.43	Setley Plain	Old Milton	Setley Plain
WSOL23 2	437137	100036	34.41	4.32	30.09	Mount Pleasant	Old Milton	Mount Pleasant
WSOL23 3	436864	099669	31.69	2.69	29.00	Mount Pleasant	Old Milton	Mount Pleasant
WSOL23 4	436834	099257	29.10	4.02	25.08	Old Milton	Becton Farm	Old Milton
WSOL23 5	436817	098412	26.76	4.99	21.77	Old Milton	Becton Farm	Old Milton
WSOL23 6	436845	097805	19.46	3.42	16.04	Stanswood Bay	Stanswood Bay	Stanswood Bay
WSOL23 7	436809	097529	17.00	3.10	13.90	Stanswood Bay	Stanswood Bay	Stanswood Bay
WSOL23 8	436120	096639	11.61	3.91	7.70	Stanswood Bay	Stanswood Bay	Milford on Sea
WSOL23 9	436298	096004	9.10	3.38	5.72	Milford on Sea	Milford on Sea	Milford on Sea
WSOL23 10	436391	095560	5.50	4.25	1.25	Lepe	Lepe or St Leonards Farm	Milford on Sea

Table 5.14. Stratotype data from the Allen and Gibbard (1993) scheme used in this study.

Reference	Easting	North.	GL	Gr Th.	Bd Ht	Previous mapping: Allen and Gibbard 1993	Previous mapping: Westaway *et al.* 2006	Revised terrace scheme
BHh	441400	105500	39.00	5.00	33.50	Beaulieu Heath	Beaulieu Heath	Beaulieu Heath
BHl	441400	105500	39.00	2.90	35.60	Beaulieu Heath	Beaulieu Heath	Beaulieu Heath
HR	421400	101000	66.00	4.00	61.50	Holmsley Ridge	Holmsley Ridge	Holmsley Ridge
LPL	440700	097800	4.00	4.00	-0.50	Lepe Lower	St Leonards Farm	Milford on Sea
LPU	445800	098600	6.00	3.60	1.90	Lepe Upper	Lepe	Milford on Sea
MPh	429600	098100	36.00	6.10	29.40	Mount Pleasant	Mount Pleasant	Mount Pleasant
MPl	429600	098100	36.00	3.70	31.80	Mount Pleasant	Mount Pleasant	Mount Pleasant
OM	424200	092000	31.00	4.50	26.00	Old Milton	Becton Farm	Old Milton
PNLh	430900	092700	0.00	7.70	-8.20	Pennington	Pennington	Pennington

Reference	Easting	North.	GL	Gr Th.	Bd Ht	Previous mapping: Allen and Gibbard 1993	Previous mapping: Westaway *et al*. 2006	Revised terrace scheme
						Lower	Lower	
PNLl	430900	092700	0.00	5.70	-6.20	Pennington Lower	Pennington Lower	Pennington
PNU	432400	092300	4.00	4.00	-0.50	Pennington Upper	Pennington Upper	Pennington
SB	447300	100300	9.00	5.40	3.10	Stanswood Bay	Stanswood Bay	Stanswood Bay
SP	430500	099400	42.00	4.00	37.50	Setley Plain	Setley Plain	Setley Plain
SW	427300	099100	55.00	4.00	50.50	Sway	Sway	Sway
TD	445000	101600	18.00	3.40	14.10	Tom's Down	Tom's Down	Tom's Down
TF	425900	092400	26.00	4.70	20.80	Taddiford Farm	Downton	Stanswood Bay
TP	425800	097200	50.00	4.60	44.90	Tiptoe	Setley Plain	Setley Plain
WH	418700	100500	73.00	4.00	68.50	Whitefield Hill	Holmsley Ridge	Whitefield Hill

Table 5.15. PASHCC (Bates *et al*. 2004, 2007; Bates and Briant 2009) section logs used in this study.

Reference	Easting	North.	GL	Gr Th.	Bd Ht	Previous mapping: Allen and Gibbard 1993	Previous mapping: Westaway *et al*. 2006	Revised terrace scheme
BOS03 S1	423010	093110	34.48	3.80	29.63	Old Milton	Old Milton	Old Milton
BOS03 S2	423080	093090	34.04	4.10	28.84	Old Milton	Old Milton	Old Milton
BOS03 S3	423300	093040	33.43	4.75	27.78	Old Milton	Old Milton	Old Milton
ST03 S1	447350	100370	5.00	4.42	0.58	Stanswood Bay	Stanswood Bay	Stanswood Bay

Table 5.16. The available borehole archive of the Western Solent used in this study. Key: GL Ground Level; Gr Th. Gravel thickness; Bd Ht Bedrock Height.

Reference	Easting	North.	GL	Gr Th.	Bd Ht	Previous mapping: Allen and Gibbard 1993	Previous mapping: Westaway *et al*. 2006	Revised terrace scheme
SU30SE1	435420	101680	39.80	4.30	34.60	Setley Plain	Beaulieu Heath	Setley Plain
SU30SE10	439420	104390	38.90	5.00	33.70	Beaulieu Heath	Beaulieu Heath	Beaulieu Heath
SU30SE11	439860	100350	27.70	3.40	23.50	Mount Pleasant	Becton Farm	Mount Pleasant
SU30SE13	437170	100640	37.80	3.95	33.25	Setley Plain	Beaulieu Heath	Setley Plain
SU30SE2	435770	100770	39.30	3.60	34.80	Setley Plain	Beaulieu Heath	Setley Plain
SU30SE3	436480	101770	38.00	2.10	35.10	Setley Plain	Beaulieu Heath	Setley Plain
SU30SE4	436640	100500	38.40	4.60	33.50	Setley Plain	Beaulieu Heath	Setley Plain
SU30SE5	437310	101790	38.20	3.90	33.70	Setley Plain	Beaulieu Heath	Setley Plain

Reference	Easting	North.	GL	Gr Th.	Bd Ht	Previous mapping: Allen and Gibbard 1993	Previous mapping: Westaway *et al.* 2006	Revised terrace scheme
SU30SE6	437170	100660	36.70	3.70	31.70	Setley Plain	Beaulieu Heath	Setley Plain
SU30SE7	438620	103390	34.80	3.00	31.70	Setley Plain	Mount Pleasant	Setley Plain
SU30SE8	438520	101070	34.90	3.30	31.00	Setley Plain	Mount Pleasant	Setley Plain
SU30SE9	438210	100200	29.50	3.30	25.40	Mount Pleasant	Old Milton	Mount Pleasant
SU30SW11	433650	102690	42.06	2.13	39.32	Setley Plain	Beaulieu Heath	Setley Plain
SU30SW4	430650	101480	43.50	2.40	39.90	Setley Plain	Beaulieu Heath	Setley Plain
SU30SW5	430150	100200	42.00	3.20	37.50	Setley Plain	Beaulieu Heath	Setley Plain
SU30SW6	433710	101800	41.20	4.30	35.80	Setley Plain	Beaulieu Heath	Setley Plain
SU30SW7	432950	100820	40.20	4.60	35.30	Setley Plain	Beaulieu Heath	Setley Plain
SU30SW8	434590	100210	39.50	5.20	33.60	Setley Plain	Beaulieu Heath	Setley Plain
SU40NW119	440500	106200	38.60	1.90	35.50	Beaulieu Heath	Beaulieu Heath	Beaulieu Heath
SU40NW120	440530	105440	38.10	0.50	35.80	Beaulieu Heath	Beaulieu Heath	Beaulieu Heath
SU40NW121	441410	105500	38.90	3.60	34.10	Beaulieu Heath	Beaulieu Heath	Beaulieu Heath
SU40NW194	442220	105380	36.45	2.50	33.35	Setley Plain	Beaulieu Heath	Beaulieu Heath
SU40NW195	442260	105360	36.56	4.40	32.06	Setley Plain	Beaulieu Heath	Beaulieu Heath
SU40NW196	442340	105300	36.98	4.20	32.18	Setley Plain	Beaulieu Heath	Beaulieu Heath
SU40NW197	442330	105270	36.97	4.30	32.17	Setley Plain	Beaulieu Heath	Beaulieu Heath
SU40NW198	442270	105300	36.71	4.90	31.31	Setley Plain	Beaulieu Heath	Beaulieu Heath
SU40NW199	442200	105330	36.01	4.00	31.11	Setley Plain	Beaulieu Heath	Beaulieu Heath
SU40NW47	441630	106390	31.39	7.32	24.07	Setley Plain	Beaulieu Heath	Old Milton
SU40NW49	443220	105770	35.45	4.19	30.80	Setley Plain	Beaulieu Heath	Beaulieu Heath
SU40NW51	443410	105770	33.47	2.13	31.03	Setley Plain	Beaulieu Heath	Beaulieu Heath
SU40NW54	443310	105690	36.33	4.27	31.46	Setley Plain	Beaulieu Heath	Beaulieu Heath
SU40NW62	443740	105660	29.90	3.05	26.85	Setley Plain	Beaulieu Heath	Setley Plain
SU40SE356	445130	100230	17.00	3.40	13.10	Tom’s Down	Tom's Down	Tom's Down
SU40SE358	446330	101630	17.30	2.60	14.40	Tom’s Down	Tom's Down	Tom's Down
SU40SE359	446330	100460	15.90	7.30	8.10	Taddiford Farm	Tom's Down	Stanswood Bay
SU40SE360	447330	101130	14.40	2.80	11.00	Tom’s Down	Tom's Down	Tom's Down

Reference	Easting	North.	GL	Gr Th.	Bd Ht	Previous mapping: Allen and Gibbard 1993	Previous mapping: Westaway *et al.* 2006	Revised terrace scheme
SU40SW10	444110	104800	32.13	3.66	28.32	Setley Plain	Beaulieu Heath	Beaulieu Heath
SU40SW100	444050	103990	33.22	1.98	31.24	Setley Plain	Mount Pleasant	Beaulieu Heath
SU40SW101	444020	103970	33.22	0.91	32.16	Setley Plain	Mount Pleasant	Beaulieu Heath
SU40SW104	444290	104440	34.23	4.88	28.74	Setley Plain	Beaulieu Heath	Beaulieu Heath
SU40SW11	444050	104740	27.10	3.20	22.98	Setley Plain	Beaulieu Heath	Setley Plain
SU40SW113	444840	103990	30.21	1.37	27.92	Setley Plain	Mount Pleasant	Setley Plain
SU40SW118	444910	103800	31.42	3.20	27.61	Setley Plain	Old Milton	Setley Plain
SU40SW119	444910	103770	30.94	2.90	24.84	Setley Plain	Old Milton	Setley Plain
SU40SW12	444100	104750	31.73	1.68	29.98	Setley Plain	Beaulieu Heath	Beaulieu Heath
SU40SW125	444740	103780	30.69	5.64	23.99	Setley Plain	Old Milton	Setley Plain
SU40SW126	444730	103780	30.77	4.88	24.52	Setley Plain	Old Milton	Setley Plain
SU40SW129	444590	103810	30.48	4.42	26.06	Setley Plain	Mount Pleasant	Setley Plain
SU40SW130	444580	103780	30.48	5.56	24.92	Setley Plain	Mount Pleasant	Setley Plain
SU40SW14	444080	104690	20.45	1.98	18.17	Setley Plain	Beaulieu Heath	Setley Plain
SU40SW146	442640	100150	21.35	3.50	17.85	Old Milton	Becton Farm	Old Milton
SU40SW147	442680	100130	21.35	3.45	17.30	Old Milton	Becton Farm	Old Milton
SU40SW158	440280	104410	39.90	0.80	39.10	Beaulieu Heath	Beaulieu Heath	Beaulieu Heath
SU40SW160	440780	102600	32.70	3.70	28.50	Setley Plain	Mount Pleasant	Setley Plain
SU40SW161	441170	104900	36.40	2.10	33.90	Beaulieu Heath	Beaulieu Heath	Beaulieu Heath
SU40SW163	441660	101500	27.70	1.90	25.20	Mount Pleasant	Old Milton	Mount Pleasant
SU40SW164	442140	104970	36.40	2.70	32.50	Setley Plain	Beaulieu Heath	Beaulieu Heath
SU40SW165	442650	100790	22.80	4.40	17.70	Old Milton	Becton Farm	Old Milton
SU40SW166	443000	104160	37.60	11.10	25.60	Setley Plain	Beaulieu Heath	Beaulieu Heath
SU40SW167	443390	102840	30.80	4.40	25.70	Setley Plain	Old Milton	Setley Plain
SU40SW168	443610	101570	23.40	3.40	19.60	Old Milton	Becton Farm	Old Milton
SU40SW175	444290	102920	26.25	0.22	23.35	Setley Plain	Old Milton	Setley Plain
SU40SW176	444270	102940	26.67	0.60	24.97	Setley Plain	Old Milton	Setley Plain
SU40SW179	444280	102960	26.73	0.25	25.58	Setley Plain	Old Milton	Setley Plain

Reference	Easting	North.	GL	Gr Th.	Bd Ht	Previous mapping: Allen and Gibbard 1993	Previous mapping: Westaway *et al.* 2006	Revised terrace scheme
SU40SW185	443810	103780	34.44	0.91	33.53	Setley Plain	Mount Pleasant	Beaulieu Heath
SU40SW29	444510	104600	30.02	3.35	26.37	Setley Plain	Beaulieu Heath	Setley Plain
SU40SW33	443760	104580	30.82	1.07	29.75	Setley Plain	Beaulieu Heath	Setley Plain
SU40SW34	443600	104460	33.77	0.91	30.57	Setley Plain	Beaulieu Heath	Beaulieu Heath
SU40SW35	443440	104350	33.77	4.42	27.52	Setley Plain	Beaulieu Heath	Beaulieu Heath
SU40SW36	443420	104280	34.14	5.33	28.04	Setley Plain	Beaulieu Heath	Beaulieu Heath
SU40SW37	443520	104340	33.35	2.90	27.25	Setley Plain	Beaulieu Heath	Beaulieu Heath
SU40SW4	443960	104850	28.68	1.14	27.54	Setley Plain	Beaulieu Heath	Setley Plain
SU40SW40	443650	104380	32.37	2.29	29.93	Setley Plain	Beaulieu Heath	Beaulieu Heath
SU40SW42	443690	104340	32.95	1.52	30.51	Setley Plain	Beaulieu Heath	Beaulieu Heath
SU40SW42	443580	104250	33.99	3.20	28.35	Setley Plain	Beaulieu Heath	Beaulieu Heath
SU40SW43	443580	104230	35.60	1.37	29.20	Setley Plain	Beaulieu Heath	Beaulieu Heath
SU40SW44	443530	104190	35.45	7.01	27.65	Setley Plain	Beaulieu Heath	Beaulieu Heath
SU40SW45	443750	104290	33.07	3.35	29.72	Setley Plain	Beaulieu Heath	Beaulieu Heath
SU40SW46	443760	104270	33.35	2.59	30.75	Setley Plain	Beaulieu Heath	Beaulieu Heath
SU40SW47	443740	104270	33.28	2.74	30.54	Setley Plain	Beaulieu Heath	Beaulieu Heath
SU40SW48	443720	104270	33.31	3.35	29.96	Setley Plain	Beaulieu Heath	Beaulieu Heath
SU40SW49	443750	104250	33.35	1.37	31.97	Setley Plain	Beaulieu Heath	Beaulieu Heath
SU40SW50	443790	104230	35.75	4.27	30.57	Setley Plain	Beaulieu Heath	Beaulieu Heath
SU40SW51	443720	104240	33.38	1.22	32.16	Setley Plain	Beaulieu Heath	Beaulieu Heath
SU40SW52	443710	104230	33.25	1.52	31.73	Setley Plain	Beaulieu Heath	Beaulieu Heath
SU40SW53	443750	104220	35.66	4.57	30.48	Setley Plain	Beaulieu Heath	Beaulieu Heath
SU40SW54	443750	104200	33.19	3.35	29.84	Setley Plain	Beaulieu Heath	Beaulieu Heath
SU40SW55	443770	104180	33.22	3.20	30.02	Setley Plain	Beaulieu Heath	Beaulieu Heath
SU40SW56	443820	104180	35.33	4.57	30.75	Setley Plain	Beaulieu Heath	Beaulieu Heath
SU40SW57	443670	104110	36.76	7.09	29.37	Setley Plain	Beaulieu Heath	Beaulieu Heath
SU40SW59	443720	104070	36.67	6.40	29.96	Setley Plain	Beaulieu Heath	Beaulieu Heath
SU40SW60	443870	104060	35.66	5.18	29.57	Setley Plain	Beaulieu Heath	Beaulieu Heath

Reference	Easting	North.	GL	Gr Th.	Bd Ht	Previous mapping: Allen and Gibbard 1993	Previous mapping: Westaway *et al.* 2006	Revised terrace scheme
SU40SW61	443890	104080	35.81	5.41	29.34	Setley Plain	Beaulieu Heath	Beaulieu Heath
SU40SW62	443900	104110	36.30	6.10	29.29	Setley Plain	Beaulieu Heath	Beaulieu Heath
SU40SW63	443940	104110	35.45	5.03	30.11	Setley Plain	Beaulieu Heath	Beaulieu Heath
SU40SW64	443880	104440	35.20	3.96	30.78	Setley Plain	Beaulieu Heath	Beaulieu Heath
SU40SW65	443960	104370	32.77	1.52	31.09	Setley Plain	Beaulieu Heath	Beaulieu Heath
SU40SW66	444030	104470	33.07	2.74	29.57	Setley Plain	Beaulieu Heath	Beaulieu Heath
SU40SW67	443800	104750	30.66	1.52	29.14	Setley Plain	Beaulieu Heath	Setley Plain
SU40SW7	444140	104500	32.31	3.05	29.26	Setley Plain	Beaulieu Heath	Beaulieu Heath
SU40SW73	444100	104390	34.75	4.50	29.79	Setley Plain	Beaulieu Heath	Beaulieu Heath
SU40SW75	444100	104300	32.71	3.66	29.05	Setley Plain	Beaulieu Heath	Beaulieu Heath
SU40SW77	444010	104280	33.10	5.03	28.07	Setley Plain	Beaulieu Heath	Beaulieu Heath
SU40SW79	443870	104710	30.63	0.46	29.72	Setley Plain	Beaulieu Heath	Setley Plain
SU40SW8	444000	104220	33.10	2.29	30.82	Setley Plain	Beaulieu Heath	Beaulieu Heath
SU40SW80	444030	104250	33.13	4.34	28.79	Setley Plain	Beaulieu Heath	Beaulieu Heath
SU40SW81	444040	104260	35.48	4.88	29.69	Setley Plain	Beaulieu Heath	Beaulieu Heath
SU40SW82	444070	104260	33.19	3.66	29.54	Setley Plain	Beaulieu Heath	Beaulieu Heath
SU40SW83	444100	104240	33.16	2.29	30.88	Setley Plain	Beaulieu Heath	Beaulieu Heath
SU40SW84	444160	104200	33.62	3.05	30.57	Setley Plain	Beaulieu Heath	Beaulieu Heath
SU40SW85	444200	104160	33.50	2.44	31.06	Setley Plain	Beaulieu Heath	Beaulieu Heath
SU40SW86	444080	104150	33.07	1.98	31.09	Setley Plain	Beaulieu Heath	Beaulieu Heath
SU40SW87	444110	104150	33.04	3.90	29.14	Setley Plain	Beaulieu Heath	Beaulieu Heath
SU40SW88	444090	104130	32.67	1.83	30.85	Setley Plain	Beaulieu Heath	Beaulieu Heath
SU40SW89	444020	104780	32.58	2.44	29.99	Setley Plain	Beaulieu Heath	Beaulieu Heath
SU40SW9	444130	104120	33.22	2.93	29.87	Setley Plain	Mount Pleasant	Beaulieu Heath
SU40SW90	444100	104100	33.68	3.43	30.25	Setley Plain	Mount Pleasant	Beaulieu Heath
SU40SW96	444270	104120	32.86	4.11	28.74	Setley Plain	Mount Pleasant	Beaulieu Heath
SU40SW97	435420	101680	39.80	4.30	34.60	Setley Plain	Beaulieu Heath	Setley Plain
SZ19NE20	419610	098140	51.10	3.30	47.50	Tiptoe	Tiptoe	Setley Plain
SZ29NE10	427860	099810	58.50	2.20	55.90	Holmsley	Woolton	Holmsley

Reference	Easting	North.	GL	Gr Th.	Bd Ht	Previous mapping: Allen and Gibbard 1993	Previous mapping: Westaway *et al.* 2006	Revised terrace scheme
						Ridge		Ridge
SZ29NE11	427290	099140	54.70	4.50	47.60	Sway	Sway	Sway
SZ29NE12	427480	097120	38.50	4.70	32.70	Mount Pleasant	Mount Pleasant	Mount Pleasant
SZ29NE13	427310	095100	30.90	4.10	25.70	Old Milton	Becton Farm	Old Milton
SZ29NE14	428630	098730	42.70	5.20	36.30	Setley Plain	Setley Plain	Setley Plain
SZ29NE15	427920	098160	44.10	2.50	40.80	Setley Plain	Setley Plain	Setley Plain
SZ29NE16	428280	095390	32.00	3.90	26.90	Old Milton	Becton Farm	Old Milton
SZ29NE17	429420	097760	37.20	3.70	32.40	Mount Pleasant	Old Milton	Mount Pleasant
SZ29NE18	429730	096920	30.40	3.20	26.30	Old Milton	Becton Farm	Old Milton
SZ29NE3	425020	098080	55.90	5.20	49.90	Sway	Sway	Sway
SZ29NE33	427420	099290	57.30	1.22	55.78	Sway	Sway	Holmsley Ridge
SZ29NE35	429300	097500	30.00	3.50	25.50	Mount Pleasant	Old Milton	Old Milton
SZ29NE4	426120	097900	48.60	3.10	45.30	Tiptoe	Tiptoe	Setley Plain
SZ29NE5	425260	096980	45.30	0.90	44.10	Tiptoe	Setley Plain	Setley Plain
SZ29NE6	426620	097500	46.00	1.80	43.00	Setley Plain	Setley Plain	Setley Plain
SZ29NE7	426350	096460	41.50	3.40	37.10	Mount Pleasant	Mount Pleasant	Mount Pleasant
SZ29NE8	426870	095800	37.20	3.80	32.10	Mount Pleasant	Old Milton	Mount Pleasant
SZ29NE9	427260	099840	60.80	4.20	56.50	Holmsley Ridge	Woolton	Holmsley Ridge
SZ29NW1	420870	098840	65.10	4.50	59.30	Holmsley Ridge	Woolton	Holmsley Ridge
SZ29NW10	422150	098430	62.80	3.40	59.10	Holmsley Ridge	Woolton	Holmsley Ridge
SZ29NW11	422420	097550	54.60	2.60	51.00	Sway	Sway	Sway
SZ29NW12	422080	096150	49.60	1.10	47.60	Tiptoe	Tiptoe	Setley Plain
SZ29NW13	422320	095080	41.00	4.70	35.90	Mount Pleasant	Mount Pleasant	Mount Pleasant
SZ29NW14	422940	095540	42.50	3.60	36.40	Mount Pleasant	Mount Pleasant	Mount Pleasant
SZ29NW16	420840	096020	42.72	4.88	36.93	Setley Plain	Setley Plain	Mount Pleasant
SZ29NW17	423060	098820	63.50	1.80	59.60	Holmsley Ridge	Woolton	Holmsley Ridge
SZ29NW18	423710	098730	62.70	3.30	57.90	Holmsley Ridge	Woolton	Holmsley Ridge
SZ29NW19	423400	095920	43.70	2.30	40.20	Setley Plain	Setley Plain	Mount Pleasant
SZ29NW2	420200	097640	51.50	3.70	47.50	Tiptoe	Tiptoe	Setley Plain
SZ29NW20	424190	097820	56.20	4.20	50.70	Sway	Sway	Sway
SZ29NW21	424330	096540	46.30	3.20	40.90	Tiptoe	Setley Plain	Setley Plain
SZ29NW3	420640	096810	53.70	2.60	50.40	Tiptoe	Tiptoe	Setley Plain

Reference	Easting	North.	GL	Gr Th.	Bd Ht	Previous mapping: Allen and Gibbard 1993	Previous mapping: Westaway *et al.* 2006	Revised terrace scheme
SZ29NW5	421740	098790	63.80	3.40	59.00	Holmsley Ridge	Woolton	Holmsley Ridge
SZ29NW56	423290	095930	44.70	2.00	40.70	Setley Plain	Setley Plain	Mount Pleasant
SZ29NW57	423190	095860	44.55	2.75	40.85	Setley Plain	Setley Plain	Mount Pleasant
SZ29NW58	423080	095920	44.90	7.10	37.10	Setley Plain	Setley Plain	Mount Pleasant
SZ29NW59	422970	095840	44.30	3.50	39.90	Setley Plain	Setley Plain	Mount Pleasant
SZ29NW6	421380	097400	56.90	2.70	53.30	Sway	Sway	Sway
SZ29NW60	422850	095800	43.95	1.70	40.55	Setley Plain	Setley Plain	Mount Pleasant
SZ29NW61	422750	095790	44.25	5.55	38.00	Setley Plain	Setley Plain	Mount Pleasant
SZ29NW67	423080	095120	38.35	1.75	36.10	Mount Pleasant	Mount Pleasant	Mount Pleasant
SZ29NW7	421390	096650	54.20	4.00	49.30	Tiptoe	Tiptoe	Setley Plain
SZ29NW8	421140	095570	42.50	3.30	38.50	Mount Pleasant	Mount Pleasant	Mount Pleasant
SZ29NW9	422580	099310	63.40	3.80	58.00	Holmsley Ridge	Woolton	Holmsley Ridge
SZ29SE1	425470	093200	30.70	2.60	27.00	Old Milton	Becton Farm	Old Milton
SZ29SE10	429940	093260	14.00	4.80	7.70	Milford on Sea	Milford on Sea	Milford on Sea
SZ29SE11	429980	092200	5.00	3.50	-0.30	Pennington	Rook Cliff	Pennington
SZ29SE2	426980	093920	27.50	1.90	24.20	Old Milton	Downton	Old Milton
SZ29SE3	426780	093160	24.20	3.00	20.40	Taddiford Farm	Downton	Stanswood Bay
SZ29SE4	427240	092130	19.90	5.60	13.40	Stanswood Bay	Hordle	Milford on Sea
SZ29SE45	429340	091660	14.02	7.62	6.40	Pennington	Rook Cliff	Milford on Sea
SZ29SE5	427700	093820	25.00	3.30	20.80	Taddiford Farm	Downton	Stanswood Bay
SZ29SE6	428590	094240	25.80	4.20	20.90	Taddiford Farm	Downton	Stanswood Bay
SZ29SE7	428390	092800	20.20	2.60	16.00	Stanswood Bay	Hordle	Stanswood Bay
SZ29SE8	429060	093880	22.20	1.20	18.70	Stanswood Bay	Hordle	Stanswood Bay
SZ29SE9	429570	094450	24.30	2.70	20.50	Taddiford Farm	Downton	Stanswood Bay
SZ29SW15	424220	093850	32.61	2.74	29.56	Old Milton	Old Milton	Old Milton
SZ29SW25	422950	094450	36.00	5.00	26.00	Old Milton	Old Milton	Old Milton
SZ29SW26	422850	094850	36.00	8.50	22.00	Old Milton	Mount Pleasant	Old Milton
SZ39NE1	435390	099890	38.70	4.70	33.50	Setley Plain	Beaulieu Heath	Setley Plain
SZ39NE10	437240	099560	29.00	0.60	28.10	Mount Pleasant	Becton Farm	Mount Pleasant

Reference	Easting	North.	GL	Gr Th.	Bd Ht	Previous mapping: Allen and Gibbard 1993	Previous mapping: Westaway *et al.* 2006	Revised terrace scheme
SZ39NE11	437800	097820	16.60	3.20	12.60	Stanswood Bay	Stanswood Bay	Stanswood Bay
SZ39NE12	437450	096380	6.60	1.80	4.00	Milford on Sea	St Leonards Farm	Milford on Sea
SZ39NE13	438110	098700	23.40	2.40	20.30	Old Milton	Becton Farm	Old Milton
SZ39NE14	438550	097380	16.10	4.80	10.80	Stanswood Bay	Stanswood Bay	Stanswood Bay
SZ39NE15	439670	099730	24.90	4.00	20.30	Old Milton	Becton Farm	Old Milton
SZ39NE16	439800	097670	14.00	4.30	9.10	Stanswood Bay	Stanswood Bay	Stanswood Bay
SZ39NE17	439910	096570	2.00	1.60	0.00	Lepe	St Leonards Farm	Milford on Sea
SZ39NE2	435400	098080	25.70	3.50	21.40	Old Milton	Becton Farm	Old Milton
SZ39NE3	435850	097390	15.80	1.90	13.20	Stanswood Bay	Stanswood Bay	Stanswood Bay
SZ39NE4	435280	097120	18.20	1.10	16.20	Stanswood Bay	Stanswood Bay	Stanswood Bay
SZ39NE5	435260	096100	11.40	8.50	2.40	Milford on Sea	Milford on Sea	Milford on Sea
SZ39NE6	435370	095540	8.20	3.40	4.20	Milford on Sea	Milford on Sea	Milford on Sea
SZ39NE7	436890	097630	16.20	1.70	14.20	Stanswood Bay	Stanswood Bay	Stanswood Bay
SZ39NE8	436150	096580	12.30	2.60	8.80	Milford on Sea	Stanswood Bay	Milford on Sea
SZ39NE9	436370	095580	4.80	3.40	0.50	Lepe	St Leonards Farm	Milford on Sea
SZ39NW12	433570	099580	32.70	3.60	27.50	Mount Pleasant	Old Milton	Mount Pleasant
SZ39NW13	433440	099060	32.20	2.00	28.50	Mount Pleasant	Old Milton	Mount Pleasant
SZ39NW14	433080	097870	29.50	2.70	23.80	Old Milton	Becton Farm	Old Milton
SZ39NW15	432950	096790	25.90	3.40	22.20	Tom’s Down	Becton Farm	Tom's Down
SZ39NW17	433760	097710	26.70	2.80	22.80	Old Milton	Becton Farm	Old Milton
SZ39NW18	434330	099230	32.60	2.80	29.40	Mount Pleasant	Old Milton	Mount Pleasant
SZ39NW19	434480	098180	28.00	4.10	23.40	Old Milton	Becton Farm	Old Milton
SZ39NW20	434350	095990	12.90	3.90	8.40	Milford on Sea	Stanswood Bay	Milford on Sea
SZ39NW21	434550	095360	10.80	2.60	6.80	Milford on Sea	Milford on Sea	Milford on Sea
SZ39NW29	434120	095390	9.14	5.49	3.35	Milford on Sea	Milford on Sea	Milford on Sea
SZ39NW3	430190	099360	41.20	4.90	35.70	Setley Plain	Setley Plain	Setley Plain
SZ39NW36	430500	095600	27.00	1.10	23.30	Taddiford	Downton	Tom’s

Reference	Easting	North.	GL	Gr Th.	Bd Ht	Previous mapping: Allen and Gibbard 1993	Previous mapping: Westaway *et al.* 2006	Revised terrace scheme
						Farm		Down
SZ39NW4	431020	096880	29.20	9.20	19.30	Old Milton	Becton Farm	Old Milton
SZ39NW5	430040	095920	27.30	2.70	23.00	Tom’s Down	Downton	Tom's Down
SZ39NW6	430800	095160	22.90	2.90	19.70	Taddiford Farm	Downton	Stanswood Bay
SZ39NW7	431240	099590	37.80	6.10	31.50	Mount Pleasant	Mount Pleasant	Mount Pleasant
SZ39NW8	431020	098330	35.20	2.40	31.60	Mount Pleasant	Old Milton	Mount Pleasant
SZ39NW9	431590	096020	23.00	4.10	17.80	Taddiford Farm	Downton	Stanswood Bay
SZ39SW1	430010	091350	3.10	3.40	-2.10	Pennington	Pennington	Pennington
SZ39SW4	432480	094660	4.50	1.40	2.20	Lepe	St Leonards Farm	Pennington
SZ49NE16	445900	098700	2.75	6.55	-3.80	Lepe	Lepe	Milford on Sea
SZ49NE17	445780	098660	7.10	7.15	-0.05	Lepe	Lepe	Milford on Sea
SZ49NE7	446090	099810	11.50	1.60	8.40	Stanswood Bay	Stanswood Bay	Stanswood Bay
SZ49NW10	444400	099600	12.00	6.25	5.75	Taddiford Farm	Tom's Down	Stanswood Bay
SZ49NW2	440820	099700	21.80	4.20	16.70	Old Milton	Becton Farm	Old Milton
SZ49NW3	440740	097830	3.70	4.80	-1.30	Lepe	St Leonards Farm	Milford on Sea
SZ49NW4	442630	099290	14.40	2.70	11.10	Taddiford Farm	Stanswood Bay	Stanswood Bay
SZ49NW5	443650	099730	16.00	2.80	12.40	Taddiford Farm	Tom's Down	Tom's Down
SZ49NW7	444600	099300	12.50	5.30	6.80	Stanswood Bay	Stanswood Bay	Stanswood Bay
SZ49NW9	440780	098810	13.10	3.95	8.85	Tom’s Down	Tom's Down	Stanswood Bay

CHAPTER SIX: THE BOURNEMOUTH REGION

6.1 Introduction

The remnant fluvial terraces of the Bournemouth region comprise aggradational units laid down by both the Solent River and the tributary River Stour. The available borehole record of the region is particularly sparse, with few terraces being represented to a degree comparable to terraces elsewhere in the Solent region. The Bournemouth area is archaeologically important (see Chapter 2.5) and therefore warrants an examination of the available data in order to assess likely correlations with the main Solent River terrace sequence. This will allow assessment to be made of the likely correlation of archaeological sites at each end of the Solent region, those located in terraces of the River Stour and the River Test.

The BGS recognises 13 terraces in the Bournemouth region (Bristow *et al*. 1991) (with a limited outcrop of a 14th terrace to the east of the district, outside this study area), which Westaway *et al*. (2006) designate S1 to S13. Terrace 8/S8 to Terrace 13/S13 (but see Terrace 13 discussion below) agree with the mapping of Allen and Gibbard (1993), however the latter scheme recognises only two terraces below Terrace 8. The Southbourne and Holdenhurst terraces are mapped as correlative to BGS Terraces 1-2 and 3-5 respectively. These units do not have laterally equivalent terraces in the Western Solent region to the east. The intervening Terrace 6/S6 and Terrace 7/S7 are not recognised in the mapping of Allen and Gibbard (1993), nor are Bournemouth equivalents of their Lepe and Pennington terraces of the Western Solent. These issues are mitigated by the fact that Terraces 6 and 7 do not survive extensively in the Stour Valley. Terrace 7 is present in small patches at either end of the River Stour's course around Bournemouth. No borehole records are available in either of these terrace outcrops. Terrace 6 remains as a single small deposit and also has no available borehole records associated with it. Analysis in this chapter will therefore concentrate on the fluvial sequence from Terrace 8 upwards.

The geometry of the remnant fluvial landforms of the region demonstrate that as the Stour migrated towards the northeast through the Pleistocene, the Solent was occupying a successively southerly course. As a result the confluence of the two rivers moved southeast during successive downcutting/climatic cycles. Figure 6.1 shows the approximate locations of the succeeding confluences, where their terraces survived and could be discerned, which then dictated the division of terrace units between the Stour and the Solent in this study. Figure 6.1 also shows the location of the available borehole records in the Bournemouth region used to reconstruct long profile projections of the terrace stratigraphy.

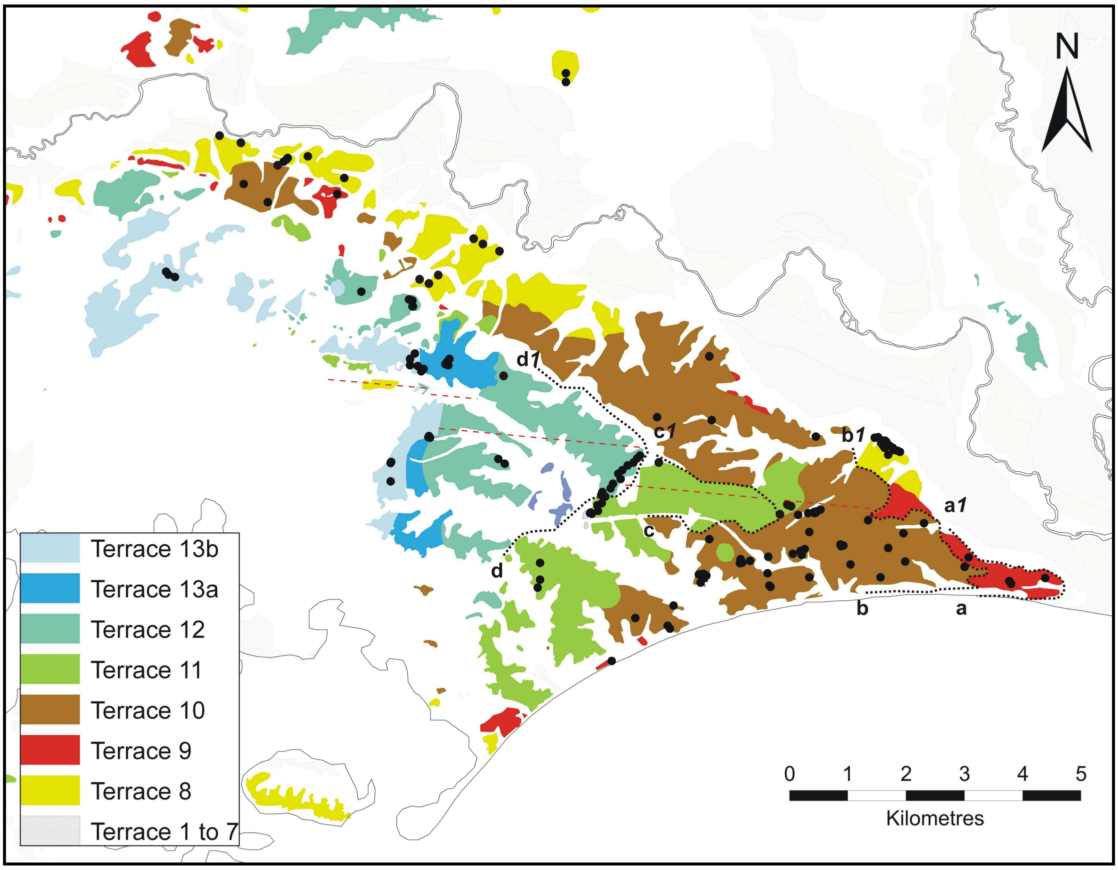


Figure 6.1. Location map of available borehole records and approximate confluences of the Stour/Solent in the Bournemouth region. Approximate locations of the confluences of the Solent and Stour rivers through the deposition of Terraces 9 to 12 are shown as: T9 a to a*1*; T10 b to b*1*; T11 c to c*1*; T12 d to d*1*. Red dashed lines show division of terraces to the Solent or Stour River.

Some higher tributary aggradations in the Stour Valley, mapped as laterally equivalent to those of the main Solent sequence, are assigned distinct nomenclature by Allen and Gibbard (1993) (see Chapter 2.5). Also, both Allen and Gibbard and Westaway *et al*. (2006) divide Bristow *et al*.'s (1991) Terrace 13 into two distinct terrace levels; the former scheme equates these to the Tiptoe and Sway terraces, the latter scheme to S13a and S13b respectively (Table 6.1).

Table 6.1. Models of the terrace stratigraphy in the Bournemouth region.

Bristow *et al.* (1991)	Allen and Gibbard (1993) model		Westaway *et al.* (2006) model	
Solent/Stour Terrace	Solent River	River Stour	Solent/Stour Terrace	MIS
T13	Sway	Sway	S13b	-
T13	Tiptoe	Tiptoe	S13a	-
T12	Setley Plain	Setley Plain	S12	-
T11	Old Milton	Old Milton	S11	-
T10	Taddiford Farm	Ensbury Park	S10	9b
T9	Stanswood Bay	West Southbourne	S9	-
T8	Milford on Sea	Knighton Lodge	S8	-

6.2 The borehole record of the Bournemouth region

The available borehole record from terraces attributed to the Solent and Stour Rivers in the Bournemouth region was assessed for inclusion in this study as set out in the Methods chapter. Boreholes that contained sands and gravels of likely fluvial origin and provided location, ground level and bedrock contact data were included. The resulting borehole dataset consists of 152 records (Table 6.2, Table 6.4, at end of chapter) that have been used for the construction of long profile projections as described in the sections below. A group of 18 borehole records in Terraces 9 and 10 are located around the approximate confluence of the Stour and Solent as those terraces were deposited. For comparative purposes they are included in the projection of terrace long profiles for each river as detailed in the appropriate sections below.

Table 6.2. Distribution of the 152 borehole records from the Bournemouth region used in the study. Stour figures in parentheses include boreholes in the area of confluence with the Solent that were used in long profile projections. These records are included in the Solent's borehole totals.

River	Terrace 8	Terrace 9	Terrace 10	Terrace 11	Terrace 12	Terrace 13a	Terrace 13b	Total
Stour	31	1 (5)	8 (24)	0	6	7	8	61
Solent	0	5	51	14	14	0	7	91
Total								152

6.3 The terraces of the Solent and Stour Rivers in the Bournemouth Region

This section will describe and define the extent of the fluvial terraces deposited by the Solent and Stour Rivers in the Bournemouth region. Terraces are presented using the nomenclature of the BGS (Bristow *et al.* (1991), Allen and Gibbard (1993) and Westaway *et al.* (2006). The 152 borehole records collated during this study have been assigned to the appropriate terrace level as defined by these schemes. The resulting long profile projections (Figures 6.2 and 6.3) show a number of issues in the stratigraphic sequences of these schemes when additional borehole data is included in projections.

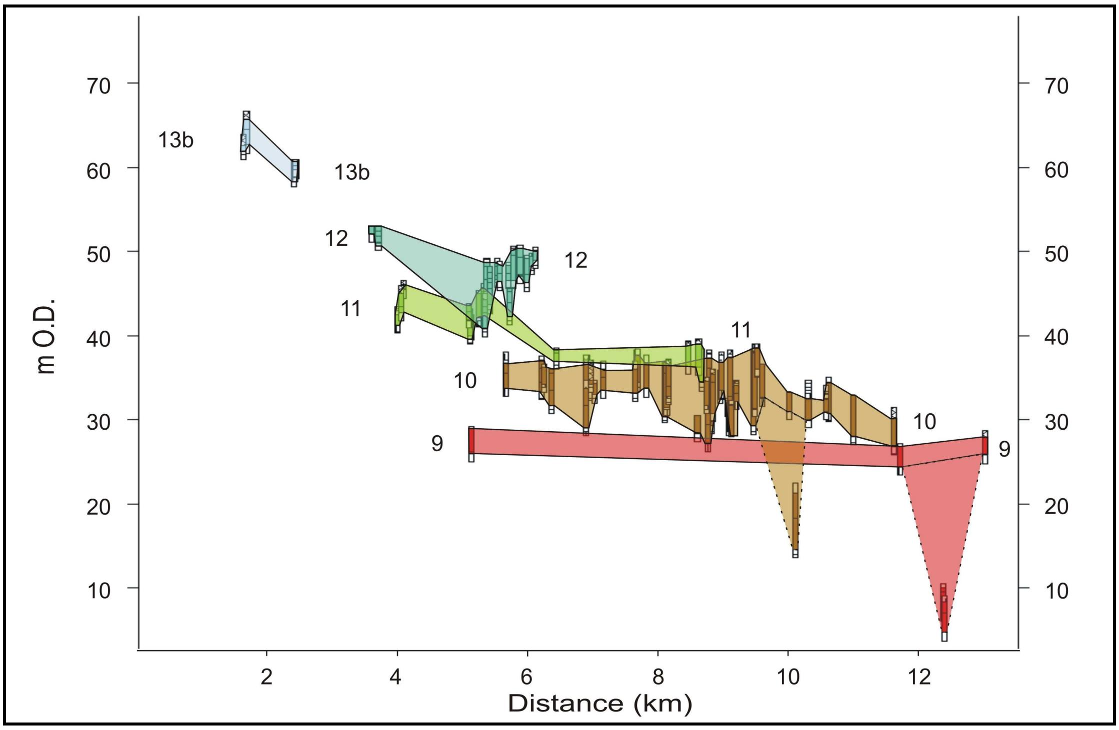


Figure 6.2. The terrace stratigraphy of the Solent River in the Bournemouth region using borehole data collated during this study. Mapping nomenclature is that of Bristow *et al.* (1991). Profile projected along N75°E with distance measured from zero at SZ 02272 91189.

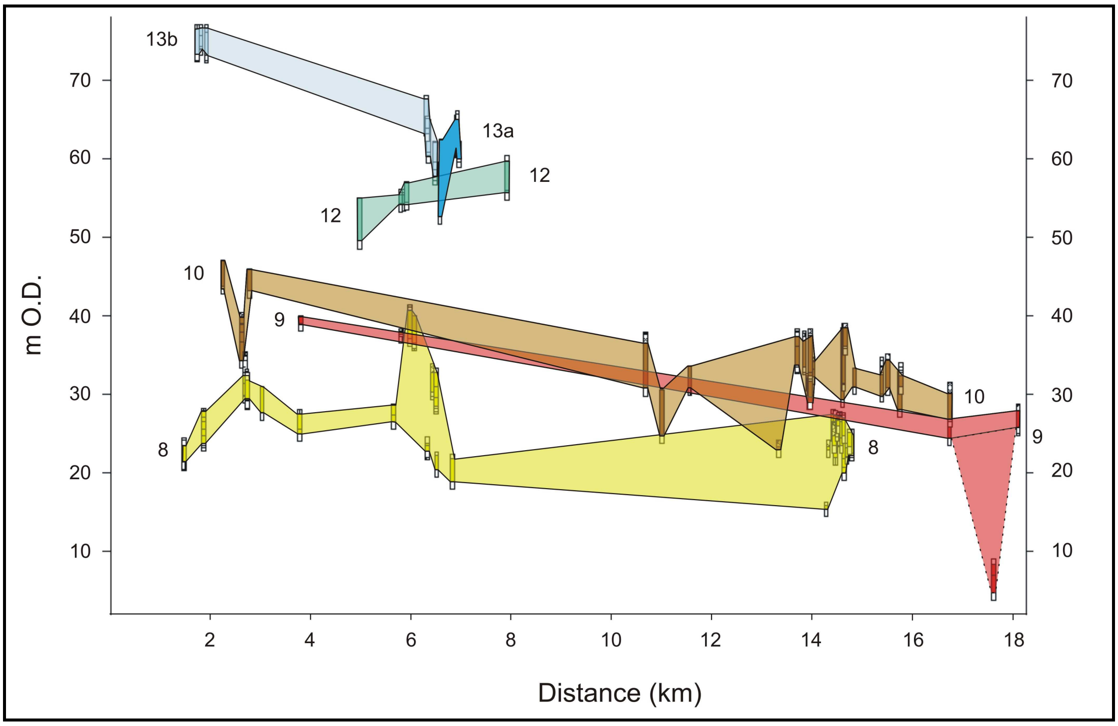


Figure 6.3. The terrace stratigraphy of the River Stour in the Bournemouth region using borehole data collated during this study. Mapping nomenclature is that of Bristow *et al.* (1991). Profile projected along N115°E with distance measured from zero at SY 99178 00013.

6.3.1 Terraces of the Solent River

Terrace 8/ Milford on Sea/ S8

A single outcrop, located just to the east of Poole Harbour (grid square SZ 050 880), is all that remains of Terrace 8 of the Solent River. The unit does not contain available borehole records and as such could not contribute to long profile projections of the Solent River terraces.

Terrace 9/ Stanswood Bay/ S9

Terrace 9 of the Solent River (Figure 6.4) is represented by 5 borehole records distributed at either end of a limited expanse of fragmentary remains of the terrace. East of Christchurch Bay (starting around grid square SZ 050 890) three patches of the terrace remain, though only a single borehole at Alum Chine (SZ09 SE76) (SZ 0724 9013) is available. Ground level here is recorded as 29.1 m O.D. and bedrock contact at 25.9 m O.D. 3 m of laminated clayey fine/medium sand and gravels overlie dense fine sand and clay bedrock of the Bracklesham Group. Downstream borehole records are found in the more extensive confluence deposits south of West Southbourne (around grid square SZ 140 910). Boreholes SZ19 SW60 (SZ 1331 9189) & 75 (SZ 1461 9154) record ground level between 27.1 m and 28.7 m O.D. and bedrock at 24.4 m to 25.8 m O.D. respectively. The former borehole records 2.4 m of sand and gravel over fine sand bedrock of the Barton Group. The latter record did not reach bedrock and in included (due to the paucity of Stanswood Bay data) as indicative of ground level and terrace surface only. Boreholes SZ19 SW329 (SZ 1400 9149) & 331 (SZ 1403 9144) appear anomalous, with ground level only around 10 m O.D., as discussed in section 6.4 below.

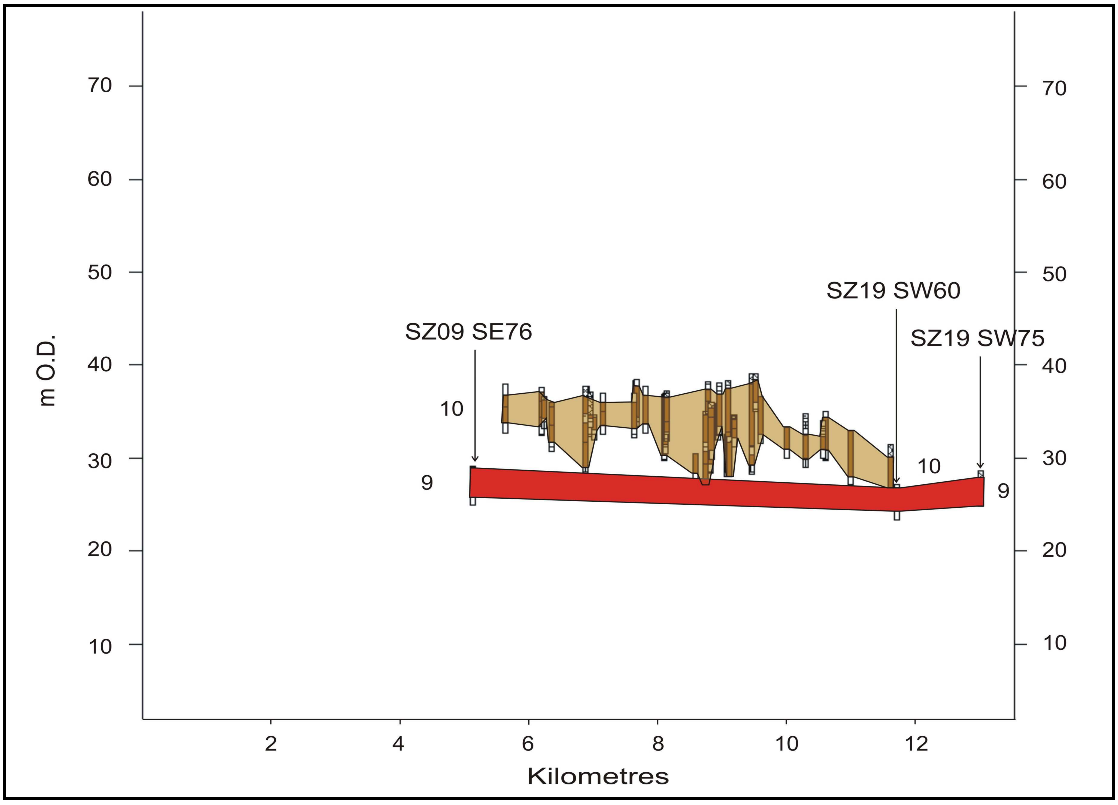


Figure 6.4. The long profile projection and distribution of data points in Terrace 9 (Bristow *et al.* 1991)/ Stanswood Bay (Allen and Gibbard 1993)/ S9 (Westaway *et al.* 2006) of the Solent River. Terrace 10 is included for comparison. Profile projected along N75°E with distance measured from zero at SZ 02272 91189.

Terrace 10/ Taddiford Farm/ S10

Terrace 10 (Figure 6.5) is the most extensive surviving terrace of the Solent, reflected in the number of borehole records available. Upstream the first remnant outcrop of Terrace 10, between Westbourne and West Hill (grid square SZ 070 900), contains four boreholes recording fluvial deposits. Ground level reaches 38 m O.D. in borehole SZ09 SE395 (SZ 0764 9086) with bedrock contact at 33.7 m O.D. Here 3.1 m of gravels with some fine to coarse sand matrix overlies compact Bracklesham Sand bedrock, representative of the 2 to 4.2 m of clast dominated deposits seen elsewhere in the unit. Downstream there survives a substantial near-continuous deposit, later dissected by a tributary stream, incorporating the area of confluence with the Stour. 47 available boreholes are located in this unit, showing considerable altitudinal variation in ground level (somewhat less so overall in bedrock contact) than may be expected for a single terrace. Ground level in this unit is as high as 39 m O.D. (SZ19 SW241 (SZ 1114 9208) and SW242 (SZ 1118 9209)) and as low as 30.5 m (SZ19 SW239 (SZ 1032 9195)). Bedrock contact is recorded from a maximum of 36 m O.D. (SZ19

SW242) to 26.8 m O.D. (SZ19 SW73 (SZ 1324 9173)) near the terrace edge. In this unit sands and gravels average 3.2 to 3.4 m in thickness, reaching up to 8 m, usually overlying Boscombe Sand Formation bedrock of the Barton Group.

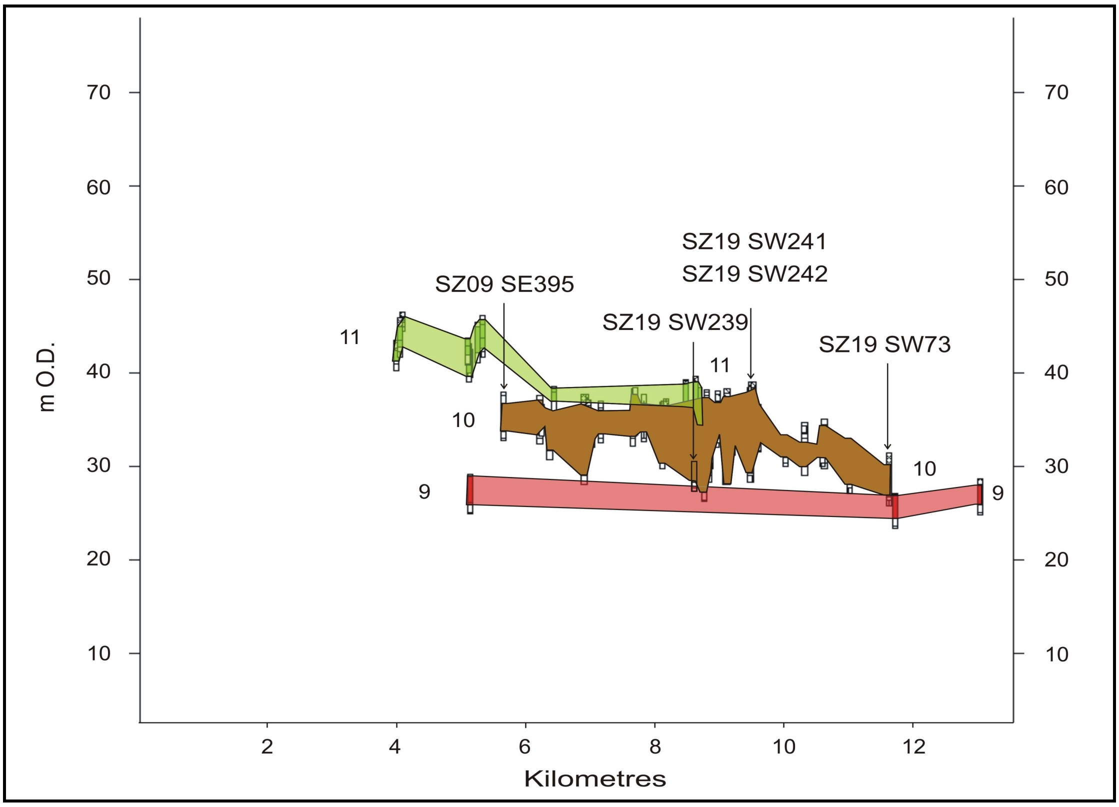


Figure 6.5. The long profile projection and distribution of data points in Terrace 10 (Bristow *et al.* 1991)/ Taddiford Farm (Allen and Gibbard 1993)/ S10 (Westaway *et al.* 2006) of the Solent River. Terraces 9 and 11 are included for comparison. Profile projected along N75°E with distance measured from zero at SZ 02272 91189.

Terrace 11/ Old Milton/ S11

Terrace 11 of the Solent River (Figure 6.6) survives in three substantial deposits represented by 14 available borehole records which are concentrated in three clusters. It is notable that their spatial distribution is restricted to two locations at the back edge of the terrace and a third at the front edge. No records are located in the upstream extent of the terrace seen east of Canford Cliffs (grid square SZ 050 890). The next deposit of Terrace 11 upstream contains three boreholes around Branksome (around grid square SZ 060 910); SZ09 SE209 (SZ 0602 9179) records ground level at 46.6 m O.D. and the nearby SZ09 SE208 (SZ 0598 9137) and SZ09 SE225 (SZ 0602 9151) show the terrace edge descending to around 43.5 m O.D. ground level. The corresponding bedrock contact ranges between 45.5 m and 41.3 m O.D. Sand and gravel deposits are relatively thin here, reaching 2.2 m thickness in SE225, over Branksome Sand bedrock of the Bracklesham Group. The next unit of Terrace 11 contains six borehole records just south of Talbot Heath (grid square SZ 060 920), near the bluff of Terrace 12 in the area. Ground level reaches 46.2 m O.D. as recorded in SZ09 SE336 (SZ 0707 92810) and descends to around 42.5 m O.D. (in SZ09 SE339 (SZ 0690 92630)) near the mapped terrace edge. Bedrock contact is recorded between 42.7 m and 40 m O.D. Deposits consist of sandy medium and coarse angular to sub angular gravel overlying sand (with weakly cemented sandstone) bedrock. The borehole records furthest downstream are found north of Boscombe (grid square SZ 100 920), within 50 to 150 m of the mapped front edge of Terrace 10. Ground level is between 39.6 m O.D. in borehole SZ19 SW254 (SZ 1023 9278) and 38.4 m O.D. in SZ19 SW244 (SZ 1028 9276), bedrock contact being at 36.3 m and 34.4 m O.D. respectively. Here 2.8 to 4 m of gravel overlies sand bedrock of the Boscombe Sand Formation. Another apparent outlier is located at the back edge of the confluence Terrace 11 unit. Borehole SZ09 SE183 (SZ 0804 9350) records ground level at 38.6 m O.D. and bedrock at 37 m O.D. (as discussed below), containing 1.3 m of very sandy gravel over sand bedrock.

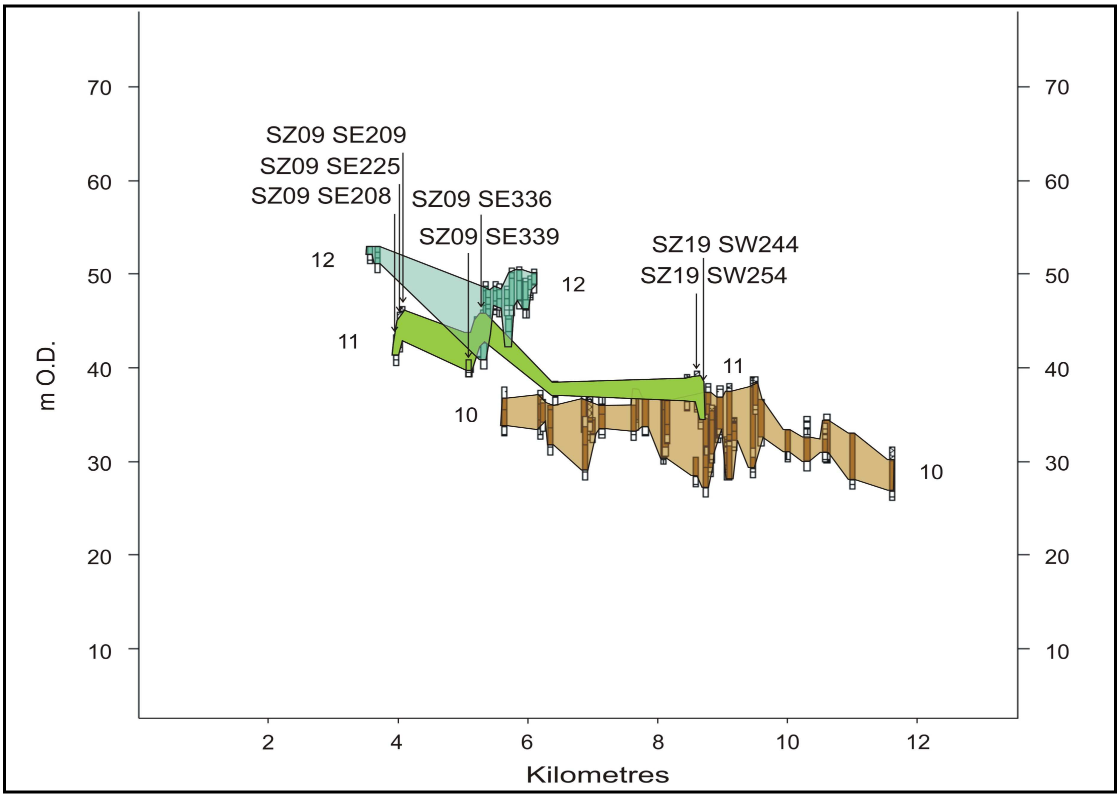


Figure 6.6. The long profile projection and distribution of data points in Terrace 11 (Bristow *et al.* 1991)/ Old Milton (Allen and Gibbard 1993)/ S11 (Westaway *et al.* 2006) of the Solent River. Terraces 10 and 12 are included for comparison. Profile projected along N75°E with distance measured from zero at SZ 02272 91189.

Terrace 12/ Setley Plain/ S12

Terrace 12 of the Solent River (Figure 6.7) extends from Upper Parkstone (SZ 050 920) upstream to a spread between Turbary Common (SZ 050 950) and Talbot Heath (SZ 070 930). Two boreholes are located towards the back edge of the terrace at Rossmore, with ground level of 53 m O.D. in SZ09 SE2 (SZ 0531 9356) and SE3 (SZ 0542 9348) and bedrock contact between 52.1 m and 51.2 m O.D. Gravel is recorded as 0.9 m and 1.8 m thick, overlying Branksome Sand bedrock. 12 boreholes are aligned along the southern extent of the downstream end of the terrace and record ground level between 50.8 m O.D. (SZ09 SE474 (SZ 0751 9345)) and 45 m O.D. (SZ09 SE466 (SZ 0706 9295)). Bedrock topography shows greater variation, with contact level ranging between 49 m O.D. SZ09 SE477 (SZ 0772 9362)) and 40.9 m (SZ09 SE466). Gravel thickness' range between 1.1 m and 4.9 m (averaging 2.8 m), consisting mostly of fine to coarse sub angular to sub rounded flints with a fine to coarse slightly silty sand matrix. Branksome Sand bedrock is slightly cemented sandstone in places.

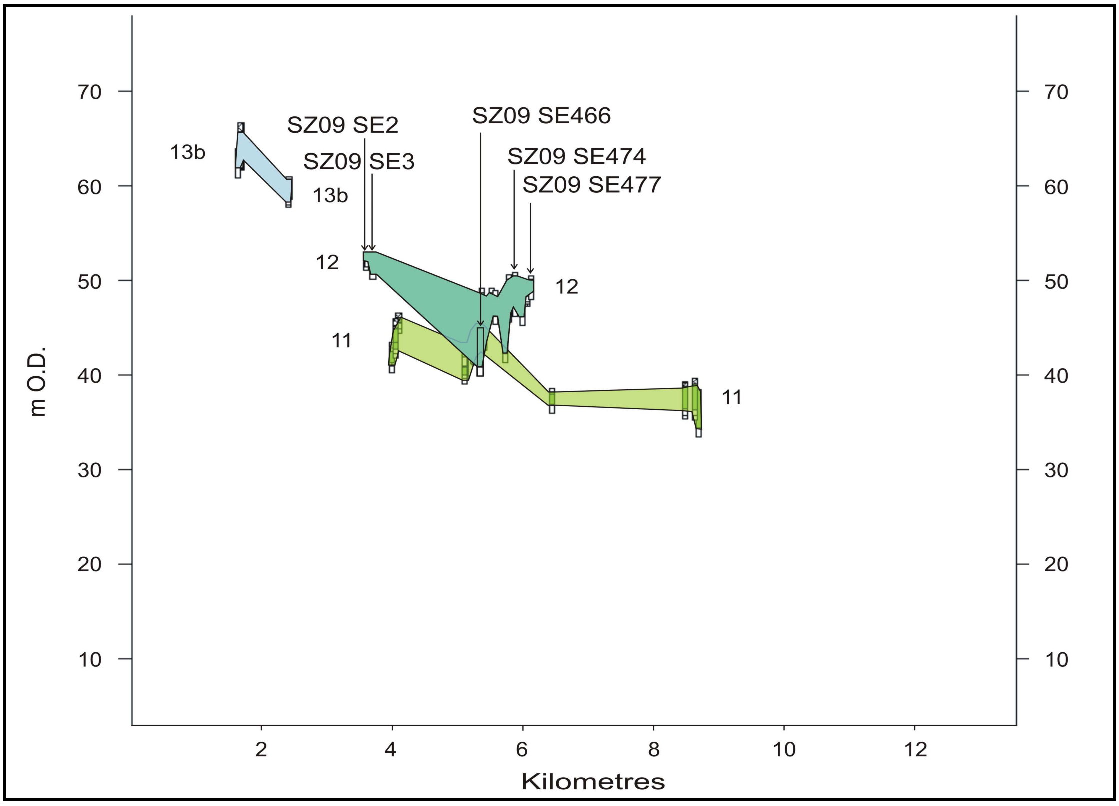


Figure 6.7. The long profile projection and distribution of data points in Terrace 12 (Bristow *et al.* 1991)/ Setley Plain (Allen and Gibbard 1993)/ S12 (Westaway *et al.* 2006) of the Solent River. Terraces 11 and 13b are included for comparison. Profile projected along N75°E with distance measured from zero at SZ 02272 91189.

Terrace 13/ Tiptoe and Sway/ S13a and b

As previously noted, the BGS' Terrace 13 (Figure 6.8) is divided into the Tiptoe (13a) and Sway (13b) terraces by Allen and Gibbard (1993) and terraces S13a and S13b by Westaway *et al.* (2006). Terrace 13a survives from Upper Parkstone (around grid square SZ 040 920), thinning out around Manning's Heath (grid square SZ 040 930). No borehole records are available in the Solent's unit of Terrace 13a, although four boreholes are located close to its' mapped edge.

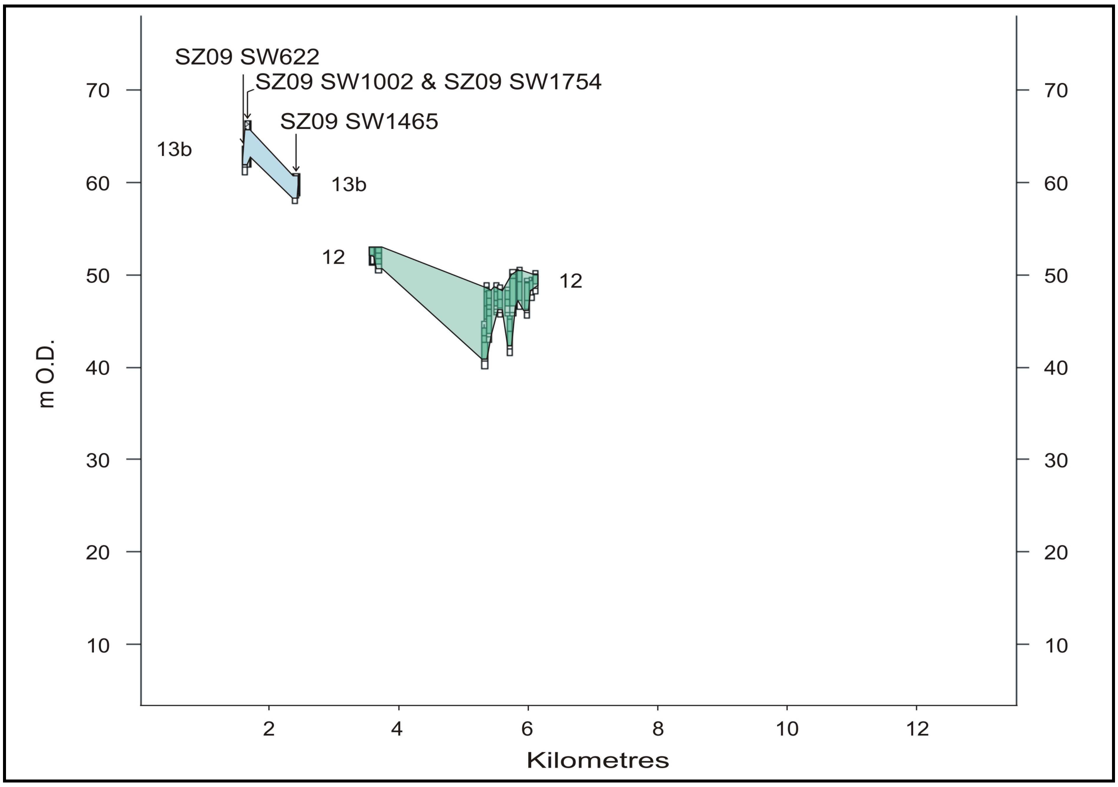


Figure 6.8. The long profile projection and distribution of data points in Terrace 13 (Bristow *et al.* 1991)/ Tiptoe (T13a) and Sway (T13b) (Allen and Gibbard 1993)/ S13a and S13b (Westaway *et al.* 2006) of the Solent River. Terrace 12 is included for comparison. Profile projected along N75°E with distance measured from zero at SZ 02272 91189.

Terrace 13b is mapped as a similar sized outcrop to 13a, extending from Constitution Hill (grid square SZ 030 920) downstream to Alderney (grid square SZ 040 940). Seven boreholes are located in Terrace 13b, with three at the back edge and four at the front edge adjacent to Terrace 13a. Ground level at the back of the terrace is recorded up to 66.7 m O.D. in SZ09 SW1002 (SZ 0349 9351) and SZ09 SW1754 (SZ 0348 9349) and bedrock at 61.9 m O.D. in SZ09 SW622 (SZ 0348 9318). Here up to 3.1 m of fine to coarse sandy gravel is interbedded with gravelly sand, overlying sand and clay bedrock of the Bracklesham Group. At the front edge of the terrace ground level is recorded in SZ09 SW1465 (SZ 0412 9393) at 61 m O.D. and bedrock at 58.7 m O.D., one of a group of four closely spaced boreholes. Gravel is 0.9 m to 1.4 m thick and overlies Bracklesham Group sand/ sand and clay bedrock.

6.3.2 Terraces of the River Stour

Terrace 8/ Knighton Lodge/ S8

Terrace 8 of the River Stour (Figure 6.9) consists of a near continuous but much dissected spread of deposits from Henbury (grid square SY 960 980) upstream to Littledown (grid square SZ 120 930) downstream. 31 available boreholes are located along the terrace, showing considerable altitudinal variation. The two boreholes furthest upstream (SZ09 NW361 (SZ 0057 9905) and SZ09 NW21 (SZ 0093 9893)) record ground level between 28.2 m and 24.4 m O.D. and bedrock between 23.7 m and 21.3 m O.D. These would appear to be anomalous as 800 m downstream the laterally equivalent terrace in the BGS mapping is recorded with ground level between 35.4 m and 31 m O.D. and bedrock between 29.9 m and 27.6 m O.D. (boreholes SZ09 NW29 (SZ 0166 9861), NW30 (SZ 0171 9865), NW33 (SZ 0173 9867) and NW383 (SZ 0207 9870)). Where recorded gravels are angular to sub angular in a sand matrix, 2.5 to 3.4 m thick, and sit on Poole Formation sand or London Clay bedrock. Around 3 km further downstream are two groups of three boreholes, neither of which appear to project onto this terrace level. At Knighton (grid square SZ 040 970) boreholes SZ09 NW400 (SZ 0489 9730), NE163 (SZ 0505 9721) and NE164 (SZ 0533 9709) record ground level between 24.6 m and 22.4 m O.D. and bedrock between 22.7 m and 18.9 m O.D. To the southwest at Merton Grange (grid square SZ 040 960) boreholes SZ09 NW256 (SZ 0429 9668), NW306 (SZ 0397 9661) and NW394 (SZ 0413 9654) record ground level between 41.3 m and 38.2 m O.D. and bedrock contact between 37.1 and 36.5 m O.D. The last outcrop of the terrace downstream, between Haddon Hill and Littledown (grid square SZ 120 930), contains the remaining closely grouped 16 boreholes in Terrace 8. Ground level ranged between 28.1 m (recorded in SZ19 SW303 (SZ 1182 9383)) and 23.7 m O.D. (recorded in SZ19 SW285 (SZ 1205 9371)). Bedrock contact varies between 26 m (recorded in SZ19 SW318 (SZ 1192 9382)) and 20 m O.D. (recorded in SZ19 SW273

(SZ 1202 9375)). Here sand and gravels of 0.5 m to 3.2 m thickness (averaging 1.8 m) overlie sand or clay bedrock of the Barton Group. A single apparent outlier (SZ19SW248 (SZ 1171 9392)) records ground level at 16.2 m O.D. and bedrock at 15.5 m O.D.

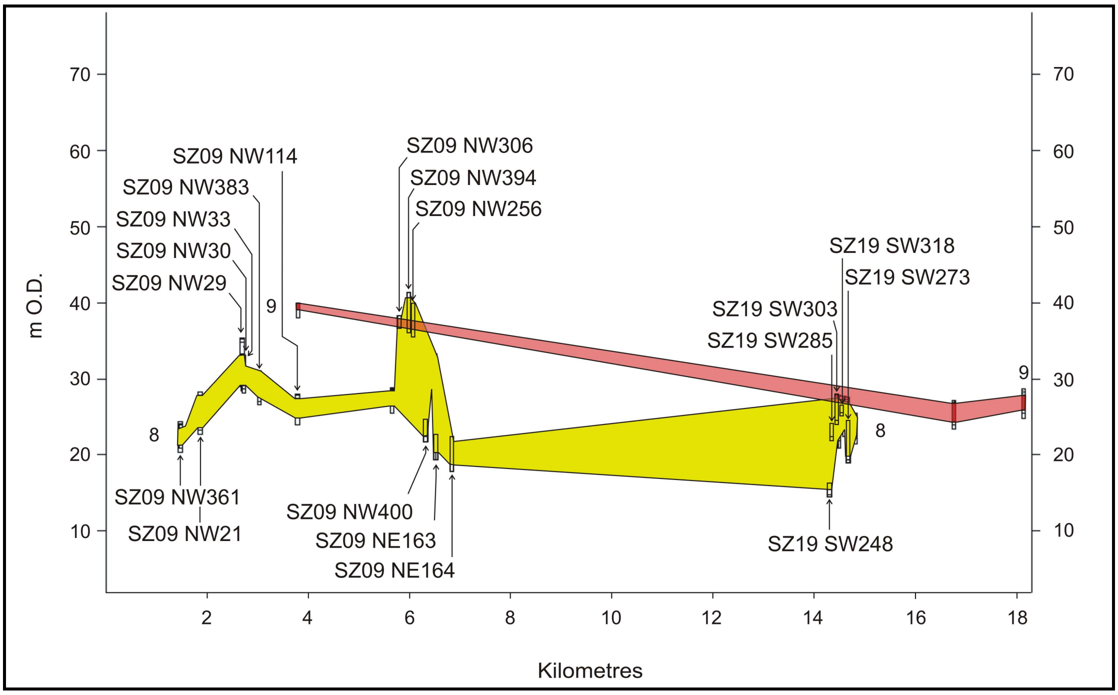


Figure 6.9. The long profile projection and distribution of data points in Terrace 8 (Bristow *et al.* 1991)/ Knighton Lodge (Allen and Gibbard 1993)/ S8 (Westaway *et al.* 2006) of the River Stour. Terrace 9 is included for comparison. Profile projected along N115°E with distance measured from zero at SY 99178 00013.

Terrace 9/ West Southbourne/ S9

Terrace 9 of the River Stour (Figure 6.10) is represented by 5 borehole records distributed at either end of the scattered fragmentary remains of the terrace. Upstream the terrace is first identified by the BGS as small patches between Henbury (around grid square SY 960 980) and Ashington (SZ 000 980), with two larger remnants south of Merley (SZ 025 980). The former spread lacks available borehole records while in the latter deposits a single borehole (SZ09 NW124 at Merley (SZ 0257 9806) records ground level at 40 m O.D. and bedrock contact at 36 m O.D. Here 1 m of fine to coarse gravel in clayey silt overlies Branksome Sand bedrock. Small, isolated patches of the terrace survive downstream, with more extensive areas mapped down the valley side from Terrace 10 around Moordown (SZ 095 945). The four remaining borehole records are found in the better preserved confluence deposits south of West

Southbourne. As discussed above in the Solent section, boreholes SZ19 SW60 (SZ 1331 9189) & 75 (SZ 1461 9154) record ground level between 27.1 m and 28.7 m O.D. and bedrock at 24.4 m O.D. in the latter. Boreholes SZ19 SW329 (SZ 1400 9149) & 331 (SZ 1403 9144) appear anomalous, with ground level only around 10 m O.D., as discussed below.

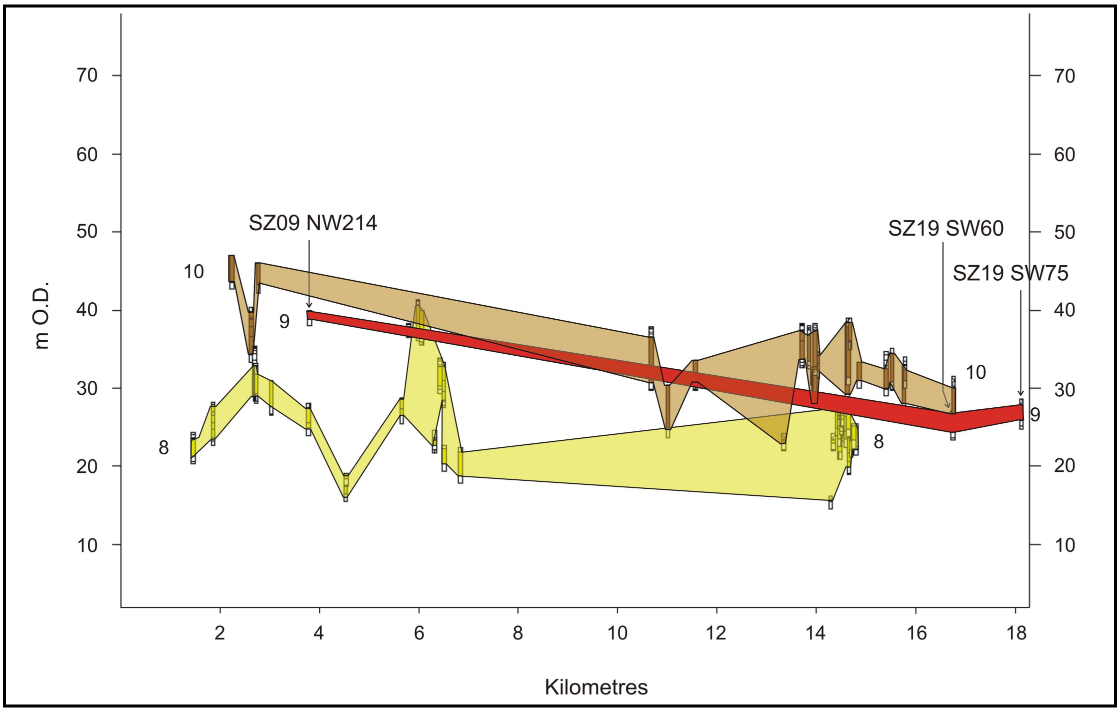


Figure 6.10. The long profile projection and distribution of data points in Terrace 9 (Bristow *et al.* 1991)/ West Southbourne (Allen and Gibbard 1993)/ S9 (Westaway *et al.* 2006) of the River Stour. Terraces 8 and 10 are included for comparison. Profile projected along N115°E with distance measured from zero at SY 99178 00013.

Terrace 10/ Ensbury Park/ S10

The River Stour Terrace 10 (Figure 6.11) contains 8 boreholes upstream of the confluence with the Solent River, and 24 in total when records in the latter area are included. An extensive unit of Terrace 10 extends upstream from the confluence to West Howe (grid square SZ 050 960). From here three patches cap Brake Hills (grid square SZ 020 970) and Stoat’s Hill (grid squares SZ 030 970 and SZ 030 960). The final upstream outcrop occurs at Merley Park (grid square SZ 000 980). This unit contains the first three available boreholes, with ground level recorded as 47 m and 46 m O.D. at Higher Merley Farm (SZ09 NW384 and NW385 (SZ 0139 9792 and SZ 0098 9823)) and 40.4 m O.D. and the front edge of the unit (SZ09 NW27 (SZ 0156 9855)). The corresponding bedrock level is seen at 43.7 m, 43.2 m and 34.4 m O.D.

The terrace contains angular to sub angular gravel in a medium sand matrix, 2.8 m to 5.5 m in thickness, overlying Broadstone Clay and sand of the Poole Formation. Downstream of West Howe 5 more boreholes indicate the presence of more than one terrace level in the unit mapped as Terrace 10. Ground level is recorded as high as 37.9 m O.D. (borehole SZ09 SE181 (SZ 0801 9427)), decreasing towards the front edge of the terrace to 33.5 m O.D. (borehole SZ09 SE424 (SZ 0894 9422)), 30.5 m O.D. (borehole SZ09 NE156 (SZ 0890 9530)) and 24.1 m O.D. (borehole SZ19 SW137 (SZ 0257 9806)). Bedrock levels in those borehole logs are recorded as 30.8 m, 30.8 m, 24.7 m and 22.9 m O.D. respectively. Sand and gravel is recorded from 5.8 m to 2.7 m towards the back of the unit in SE181 and SE424, and from 5.8 m to 0.5 m at the front of the unit in NE156 and SW137. The former group overlies sand bedrock of the Branksome Sand Formation and the latter the Boscombe Sand of the Barton Group. The remaining 16 boreholes in the region of the confluence with the Solent River were discussed above.

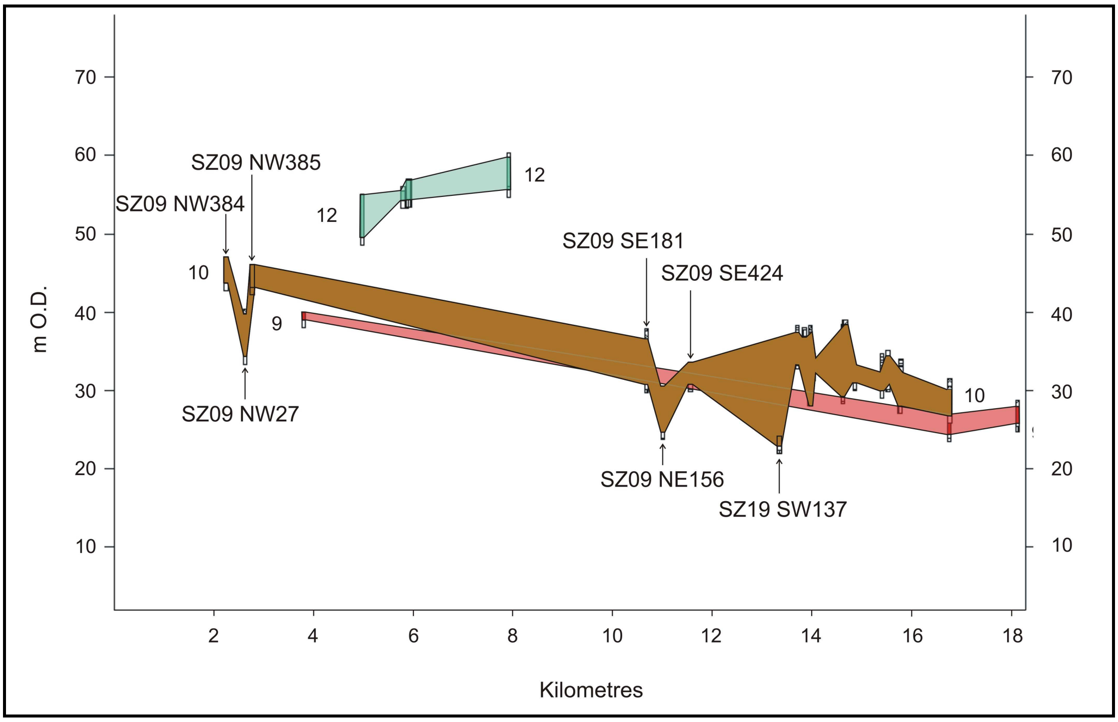


Figure 6.11. The long profile projection and distribution of data points in Terrace 10 (Bristow *et al.* 1991)/ Ensbury Park (Allen and Gibbard 1993)/ S10 (Westaway *et al.* 2006) of the River Stour. Terraces 9 and 12 are included for comparison. Profile projected along N115°E with distance measured from zero at SY 99178 00013.

Terrace 11/ Old Milton/ S11

Five small outcrops are all that remain of Terrace 11 of the River Stour; on Gravel Hill (grid square SZ 010 970); Stoat's Hill (grid square SZ 030 970), and around Bearwood (grid squares SZ 040 950 and SZ 050 950). None of these deposits contain available borehole records and as such could not contribute to long profile projections of the River Stour terraces.

Terrace 12/ Setley Plain/ S12

Terrace 12 of the River Stour (Figure 6.12) remains as various scattered remnants along the course of the river in the Bournemouth area, but only three of these units contain any of the six available borehole records. At Canford Heath (grid square SZ 020 960) borehole SZ09 NW407 (SZ 0298 9640) records ground level at 55 m O.D. and bedrock contact at 49.5 m O.D. 5.5 m of gravels overlie Broadstone Clay of the Poole Formation. A nearby group of four boreholes around 800 m downstream record ground level between 57 m to 56 m O.D. and bedrock between 54.4 m and 54.2 m O.D. (in SZ09 NW287 (SZ 0386 96150) and SZ09 NW484 (SZ 0379 96270) respectively). Here 1.2 m to 2.4 m of fine to coarse sandy gravel, clayey in places, overlies Branksome Sand of the Bracklesham Group. The remaining borehole is located downstream at Knighton Heath (SZ 0540 9497), where SZ09 SE53A records ground level at 60.4 m O.D. and bedrock contact at 55.6 m O.D. Sand and gravel is 4.1 m thick overlying Poole Formation clay.

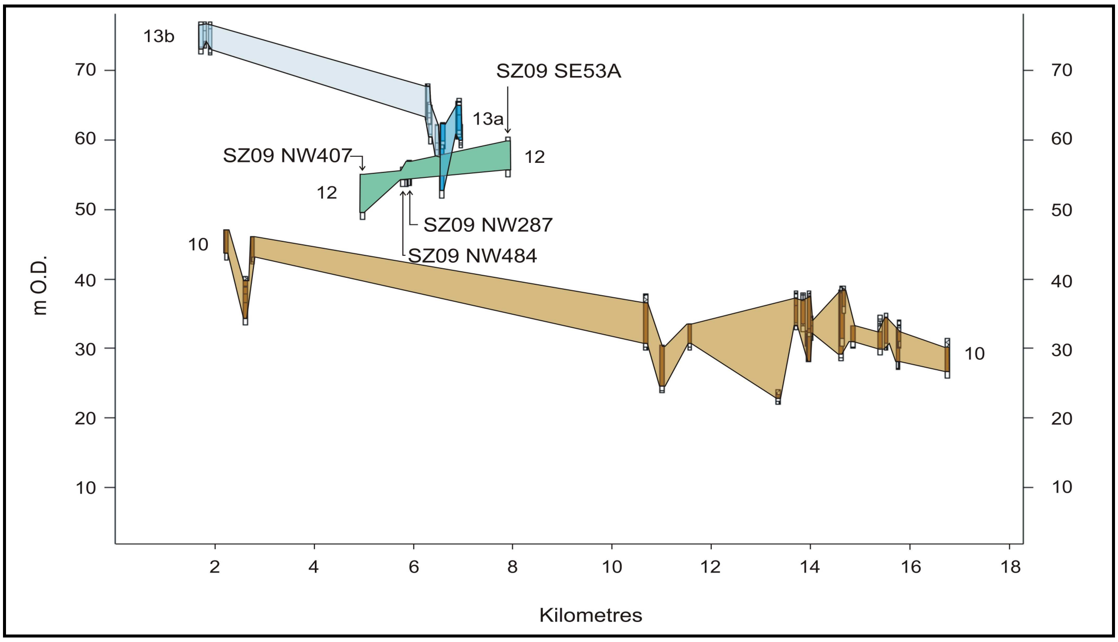


Figure 6.12. The long profile projection and distribution of data points in Terrace 12 (Bristow *et al.* 1991)/ Setley Plain (Allen and Gibbard 1993)/ S12 (Westaway *et al.* 2006) of the River Stour. Terraces 10 and 13a/13b are included for comparison. Profile projected along N115°E with distance measured from zero at SY 99178 00013.

Terrace 13/ Tiptoe and Sway/ S13a and b

Terrace 13 of the River Stour (Figure 6.13) is again divided into the Tiptoe (13a) and Sway (13b) terraces by Allen and Gibbard (1993) and terraces S13a and S13b by Westaway *et al.* (2006), as were the equivalent Solent River deposits (above). At Canford Heath a substantial unit is mapped as the location of the Terrace 13b to Terrace 13a transition. Seven boreholes are available in the latter unit, the only occurrence of Terrace 13a of the Stour, and five in the former. Ground level in Terrace 13a here is recorded between 66 m O.D. (borehole SZ09 NW449 (SZ 0448 9526)) and 59.6 m O.D. (borehole SZ09 NW277 (SZ 0400 9505)) and bedrock between 61.5 m O.D. (borehole SZ09 NW447 (SZ 0441 9517)) and 52.7 m O.D. (SZ09 NW277); 1.4 m to 3.7 m of sandy gravels overlie sands or clays of the Bracklesham Group. In Terrace 13b ground level is recorded between 68.1 m O.D. (borehole SZ09 NW464 (SZ 0381 9525)) and 62.2 m O.D. (borehole SZ09 NW279 (SZ 0394 9514)) and bedrock between 57.7 m O.D. and 52.7 m O.D. in the same boreholes logs. Fine to coarse sandy, clayey gravel between 1.8 m to 4.7 m thick again overlies sands or clays of the Bracklesham Group.

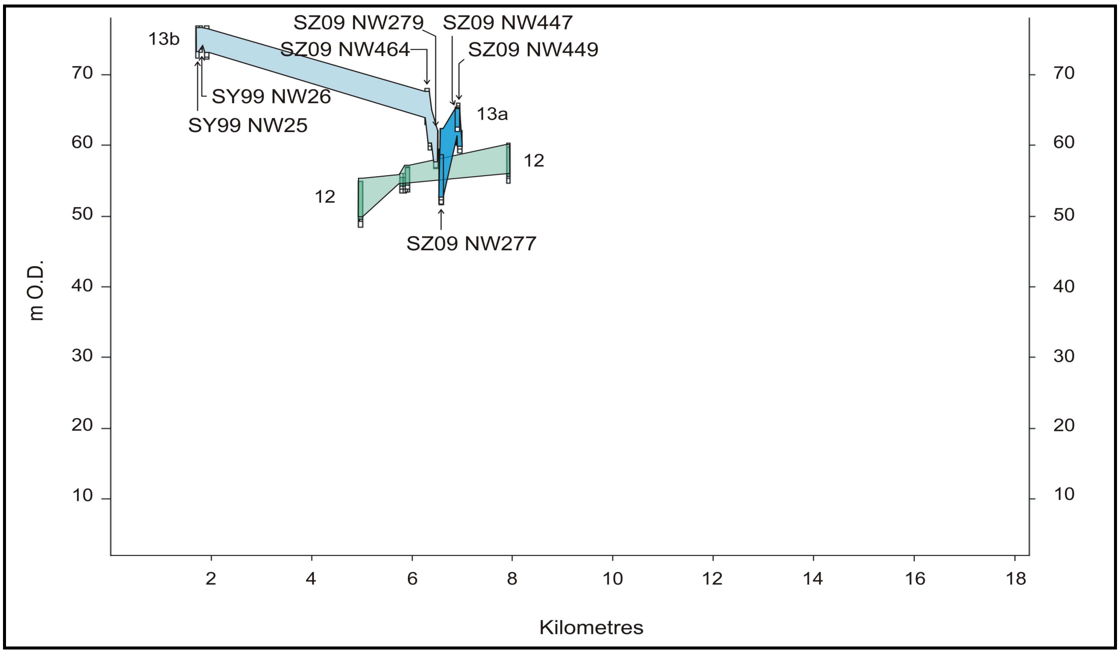


Figure 6.13. The long profile projection and distribution of data points in Terrace 13 (Bristow *et al.* 1991)/ Tiptoe (T13a) and Sway (T13b) (Allen and Gibbard 1993)/ S13a and S13b (Westaway *et al.* 2006) of the River Stour. Terrace 12 is included for comparison. Profile projected along N115°E with distance measured from zero at SY 99178 00013.

An examination of the long profile at this location (see Figure 6.19, below) shows little differentiation in the ground and bedrock levels, as discussed below. Terrace 13b is first identified upstream at Notting Hill (grid square SY 950 970). From there a scattered collection of outcrops of various extents remain, largely without available borehole records, until the unit at Canford Heath. The three boreholes furthest upstream in Terrace 13b are located at Corfe Hills (grid square SY 990 960). Ground level is recorded as 77 m O.D. in each, with bedrock between 73.2 m and 74.2 m O.D. (SY99 NE25 (SY 9981 9665) and SY99 NE26 (SY 9970 9669) respectively). Here 1.5 m to 3.2 m of sandy gravel with some clay overlies Parkstone Clay of the Poole Formation.

6.4 Reassessing the terrace stratigraphy of the Bournemouth region

This section will describe the location and data of borehole records that have been reassigned in this study and outline the reasoning behind those changes made. Figure 6.14 shows the location of reassigned boreholes and the corresponding terrace mapping revisions that resulted. Borehole records that have been reassigned are numbered as in Table 6.3 and discussed in the relevant sections below. Revised long profile projections of the terrace stratigraphies of the Solent River and River Stour are presented in Figures 6.15 and 6.16 respectively.

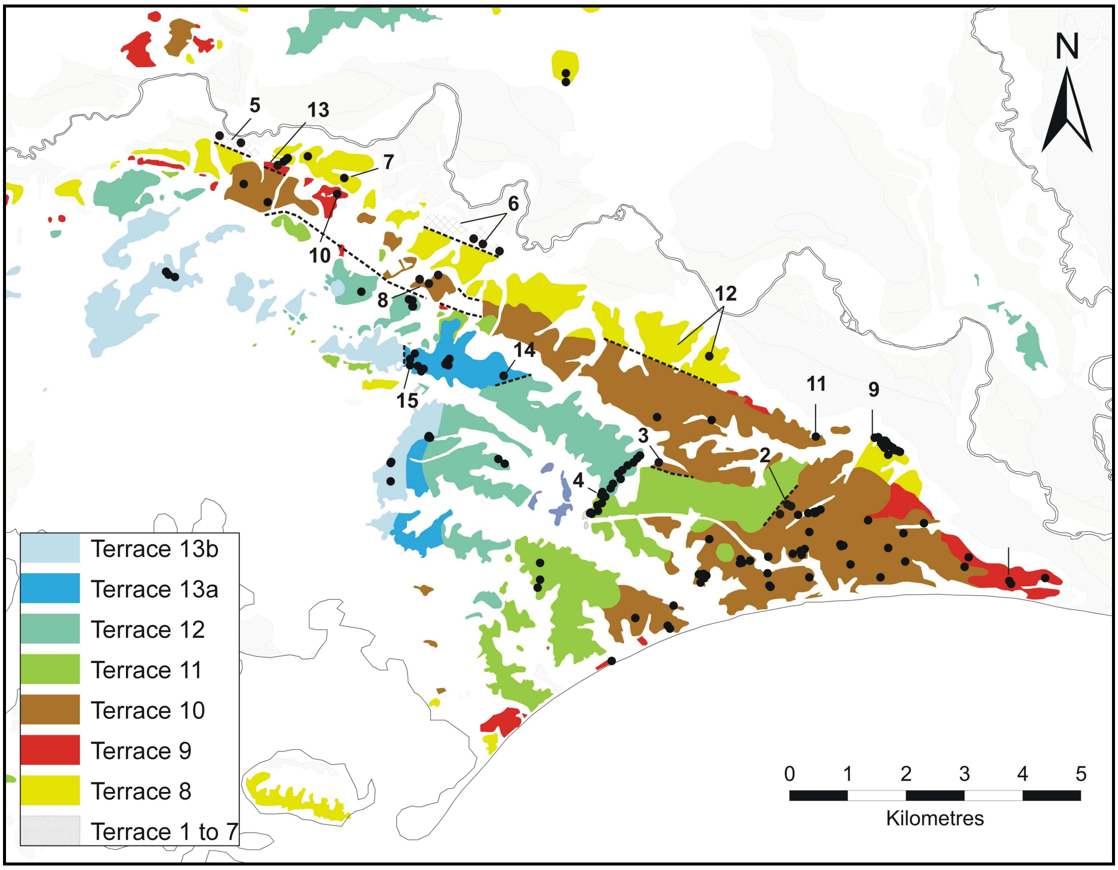


Figure 6.14. Mapping of the terrace stratigraphy of the Solent River and River Stour in the Bournemouth region as reassigned by this study (cf. Figure 6.1). Numbers show borehole records reassigned as in Table 6.3 and discussed in the appropriate sections below. Dashed lines show extent of mapping alterations.

Table 6.3. Adjustments made to terrace correlations and borehole data in the Bournemouth region record. Columns 4, 5 and 6 show the mapping schemes of Bristow *et al.* (1991), Westaway *et al.* (2006) and Allen and Gibbard (1993) respectively. Columns 7 and 8 show the revised attribution and rationale.

			Previous mapping				
Fig. Note	Reference	River	BGS	W. *et al.*	A. & G.	Revised terrace	Rationale
1	SZ19 SW329 and 331	Solent	Terrace 9	S9	Stanswood Bay	Excluded	Erroneous location data
2	SZ19 SW161, 244, 245 and 254	Solent	Terrace 11	S11	Taddiford Farm	Terrace 10	Altitudinally more consistent; near terrace boundary
3	SZ09 SE183	Solent	Terrace 11	S11	Old Milton	Stour Terrace 10	Altitudinally and geographically more consistent; near terrace boundary
4	SZ09 SE466	Solent	Terrace 12	S12	Setley Plain	Terrace 11	Altitudinally more consistent; near terrace boundary
5	SZ09NE163, 164 and 400	Stour	Terrace 8	S8	Knighton Lodge	Terrace 1 to 7	Altitudinally more consistent
6	SZ09NW21 and 361	Stour	Terrace 8	S8	Knighton Lodge	Terrace 1 to 7	Altitudinally more consistent
7	SZ09 NW114	Stour	Terrace 8	S8	Knighton Lodge	Excluded	Altitudinally low for Terrace 8 but unable to reclassify
8	SZ09 NW256 306 and 394	Stour	Terrace 8	S8	Knighton Lodge	Terrace 10	Altitudinally and geographically more consistent
9	SZ19 SW248	Stour	Terrace 8	S8	Knighton Lodge	Excluded	Altitudinally low for Terrace 8 but unable to reclassify
10	SZ09 NW124	Stour	Terrace 9	S9	West Southbourne	Terrace 9	Note bedrock level not unequivocally defined
11	SZ19 SW137	Stour	Terrace 10	S10	Ensbury Park	Excluded	Altitudinally low for Terrace 10 but unable to reclassify
12	SZ09 NE156	Stour	Terrace 10	S10	Ensbury Park	Terrace 8	Altitudinally more consistent
13	SZ09 NW27	Stour	Terrace 10	S10	Ensbury Park	Terrace 9	Altitudinally more consistent
14	SZ09 SE53A	Stour	Terrace 12	S12	Setley Plain	Terrace 13a	Data is more consistent with Terrace 13a in the locality
15	SZ09 NW277	Stour	Terrace 13	S13a	Tiptoe	Excluded	Altitudinally low for Terrace 13a, probably located on eroded terrace edge

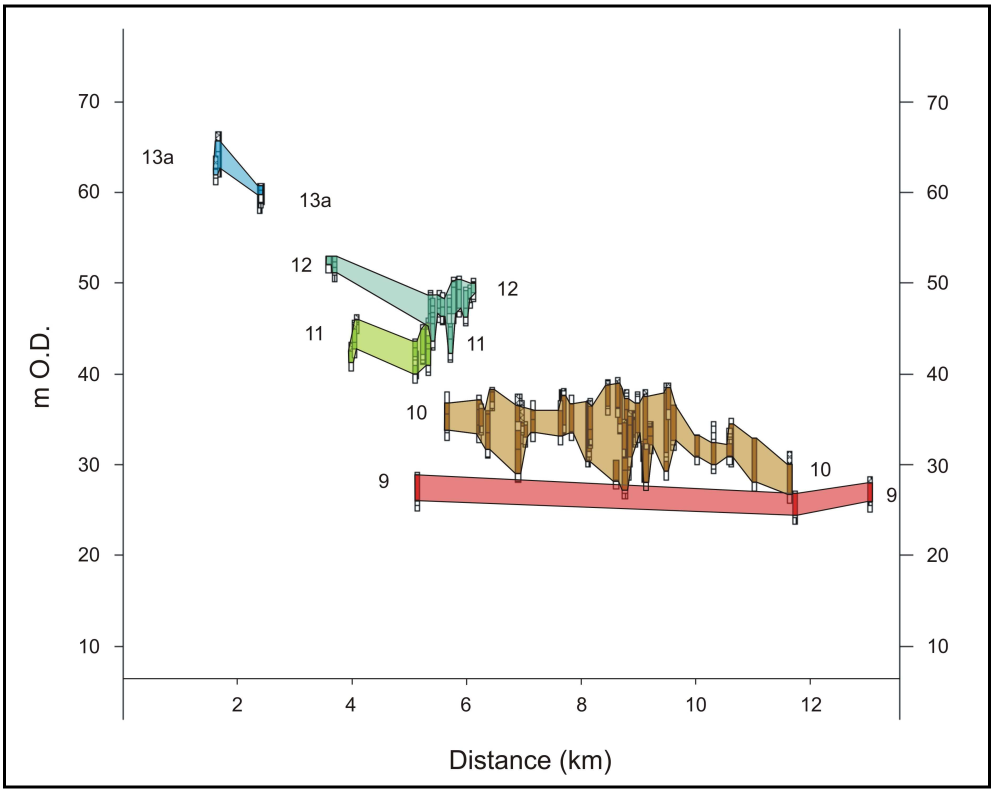


Figure 6.15. The terrace stratigraphy of the Solent River in the Bournemouth region as assigned by this study. Profile projected along N75°E with distance measured from zero at SZ 02272 91189.

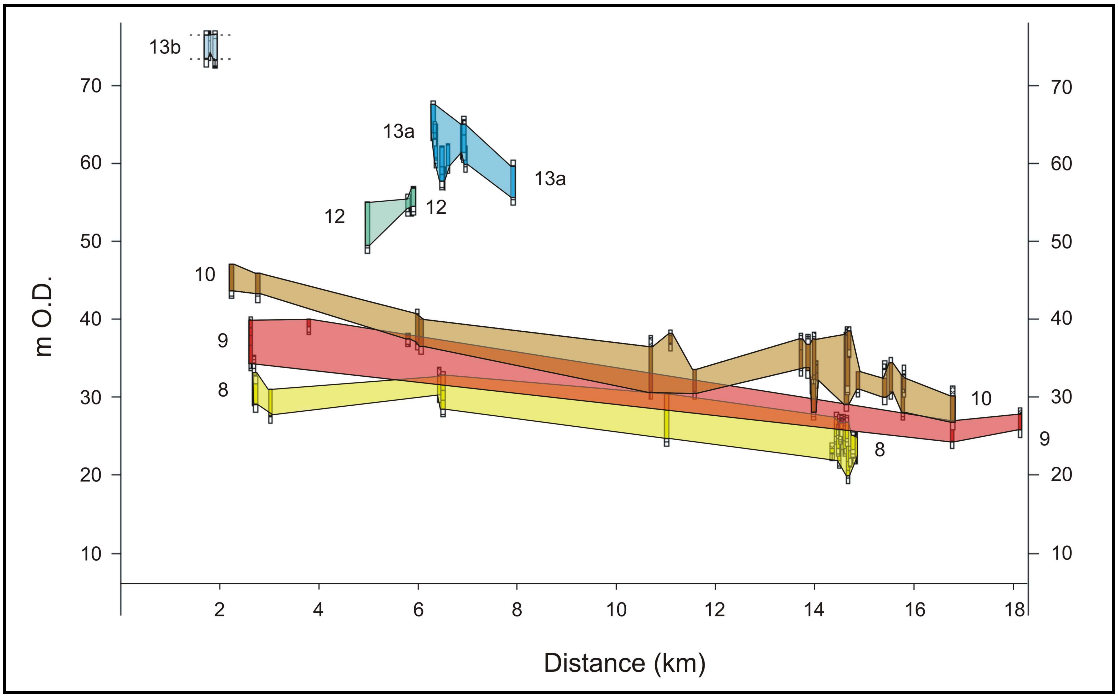


Figure 6.16. The terrace stratigraphy of the River Stour in the Bournemouth region as assigned by this study. Profile projected along N115°E with distance measured from zero at SY 99178 00013.

6.4.1 Terraces of the Solent River

Terrace 8

Terrace 8 of the Solent River is mapped in the Bournemouth region by the BGS as a single small deposit just east of Poole Harbour. No available borehole records are located in the unit and as such Terrace 8 is not represented in the long profile projection of Solent River terraces.

Terrace 9

When projected in the Solent River long profile the ground level of boreholes SZ19 SW329 and 331 (Figure 6.14, note 1) at Southbourne appear to have been recorded erroneously low. OS mapping of the area shows numerous spot heights of around 28 to 29 m O.D., while the driller's logs record ground level at just 10.5 and 9 m O.D. It is likely that the co-ordinates given for the borehole records, although reportedly within ±10 m, are incorrect. Bell Vue Road continues northeast until it crosses the modern River Stour, descending to less than 6 m O.D. as it does so, with the boreholes likely located at this end of the road. Records SZ19 SW329 and 331 were therefore not used in the Solent River long profile.

Terrace 10

Boreholes SZ19 SW161, 244, 245 and 254 (Figure 6.14, note 2) around Boscombe are located in Terrace 11 as mapped by the BGS, within 100 m of the transition to Terrace 10. Although high for the latter terrace the records project considerably lower (by 5 to 6 m) than those in the former terrace located 3 km upstream. The considerable overlap with Terrace 10 deposits nearby suggests that the boreholes belong to that terrace level rather than representing the front edge of Terrace 11. The mapping of Terrace 10 has subsequently been adjusted at the location. A closer examination of the Terrace 10 borehole logs in the Stour/Solent confluence region in cross section (Figure 6.17) shows that while ground level varies by up to 8 m amplitude it is not easy/simple/possible to define more than a single terrace deposit. There is not the same degree of variety in the bedrock contact level in comparison to recorded ground level, with less discernable change in bedrock relief either in long profile or a northwest – southeast cross section until the final few boreholes in each. The topography would appear to show a single terrace with a greatly modified ground level, ultimately eroding northeast towards the modern Stour and southeast towards the Solent.

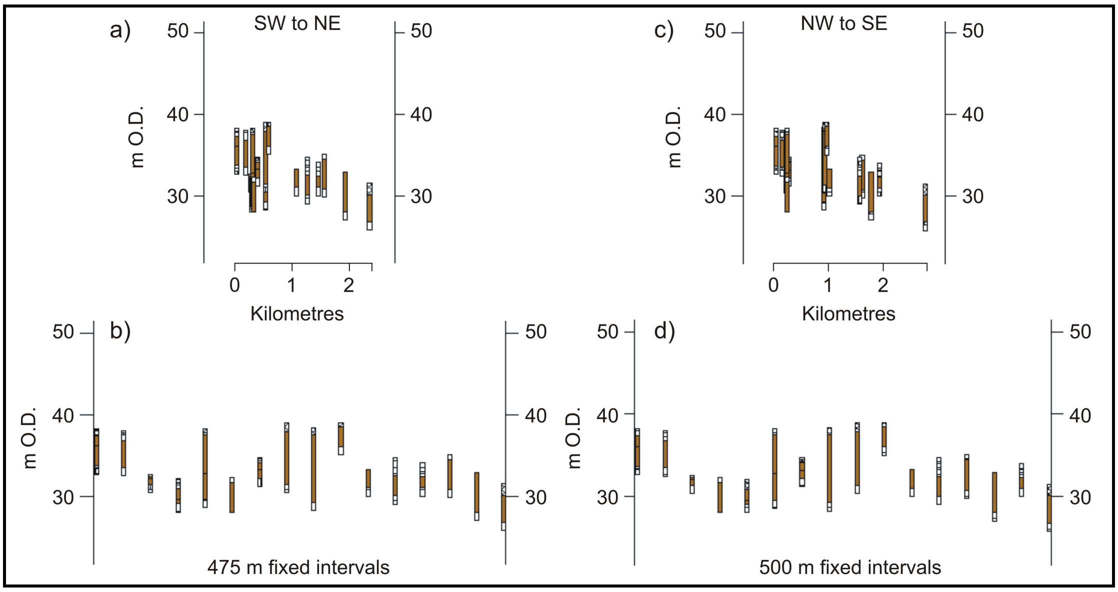


Figure 6.17. Long profile and cross section projections of Terrace 10 at the confluence of the River Stour and Solent River. a) Close up of the Solent River long profile projection of Terrace 10; b) Borehole to borehole profile of records shown in a); Profile projected along N75°E with distance measured from zero at SZ 10097 91760; c) NW to SE cross section of the same logs; d) Borehole to borehole profile of records shown in c); Profile projected along N165°E with distance measured from zero at SZ 10504 93580.

Terrace 11

Borehole SZ09 SE183 (Figure 6.14, note 3) is located on the edge of Terrace 11 in the confluence area of the Solent and Stour Rivers. The area is close to Terrace 10 deposits of the River Stour, and the borehole projects at a level more consistent with that unit. As such the record has been reassigned to Terrace 10 of the River Stour, with appropriate adjustments to the mapped extent of the terrace.

Terrace 12

Borehole SZ09 SE466 (Figure 6.14, note 4) is located near the transition from Terrace 12 to Terrace 11 at Talbot Heath. When viewed in a section long profile of the transition area (Figure 6.18) it would appear that SE466 is more consistent with the level of Terrace 11. The record has been reassigned to Terrace 11 and the appropriate adjustments have been made to the mapped extent of the terrace The minor nature of the adjustment needed (~50 m movement of the Terrace 11/10 boundary) is not discernable at the mapped scale of Figure 6.14.

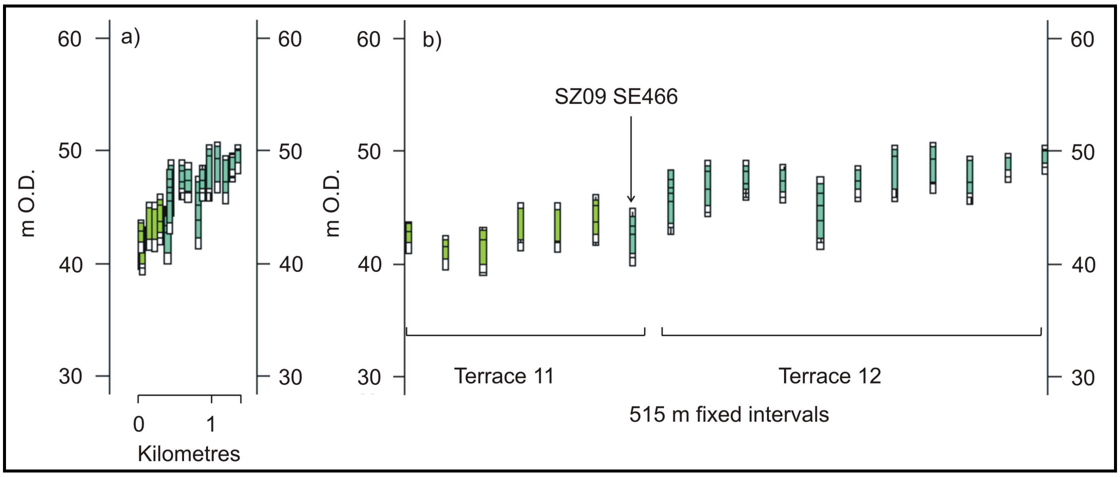


Figure 6.18. Long profile projection of Terraces 11 to 12 of the Solent River. a) Close up of the Terrace 11 to 12 transition; b) Borehole to borehole profile of records shown in a). Profile projected along N225°E with distance measured from zero at SZ 06658 92346.

Terraces 13a and 13b

Terrace 13a of the Solent River as mapped by Allen and Gibbard (1993) and Westaway *et al*. (2006) does not contain available borehole records. The seven borehole records described above located at the back and front edges of the Solent Terrace 13b are close to an outcrop of Terrace 13a deposited by the Stour River. It can be seen from long profile projections (Figures 6.2 and 6.3, above) that altitudinally these two units appear to be laterally equivalent. Terrace 13b of the Stour, as seen at Corfe Mullen (see above and below), is considerably higher than either of these units. It would seem likely therefore that the area of Solent deposits mapped as Terraces 13a and 13b are instead a single outcrop of Terrace 13a, with borehole records located at the back and front edges of that unit.

6.4.2 Terraces of the River Stour

Terrace 8

The upstream end of Terrace 8 of the River Stour shows evidence of a number of potential correlation issues. Three boreholes (SZ09 NE163, 164 and 400 (Figure 6.14, note 5)) between Knighton Cottages and Bear Wood, east of Canford Park, are located towards the front edge of Terrace 8 near a deposit of Terrace 1 to 7. Altitudinally the group fit better if attributed to the latter rather than Terrace 8. Similarly, borehole SZ09 NW361 at Merley Hall Farm and the nearby SZ09 NW21 (Figure 6.14, note 6) are located around 30 m from the transition from Terrace 8 to terraces mapped as 1 to 7. They are more likely to be laterally equivalent to Terraces 1 to 7, being around 10 m lower in ground level and bedrock contact than Terrace 8 just downstream. Borehole SZ09 NW114 (Figure 6.14, note 7) is also excluded from long profile projections on altitudinal grounds. It is geographically difficult to correlate the borehole to another terrace level without more data, as to attribute the location to Terrace 1 to 7 would require reassigning a large area of Terrace 8 on a single data point. It is possible that the borehole is simply located on a degraded terrace edge. Boreholes SZ09 NW256, 306 and 394 (Figure 6.14, note 8), south of Canford Park, are located near the edge of a deposit mapped as Terrace 8. In long profile they project as laterally equivalent to Terrace 10, and reassigning the locality fits geographically with deposits of Terrace 10 both upstream and downstream. The unit and borehole logs have been accordingly reassigned. At the downstream extent of the River Stour Terrace 8, borehole SZ19 SW248 (Figure 6.14, note 9) is excluded from the long profile projection as ground level and bedrock contact appears erroneously low. A group of 15 borehole records extending to the immediate southeast record both ground and bedrock level up to 10 m higher, while appearing to project as a coherent terrace level.

Terrace 9

Just three available boreholes are located in Terrace 9 of the River Stour. At the upstream end of the terraces’ distribution a single borehole, SZ09 NW124 (Figure 6.14, note 10), only reached 4 m in depth. Description of beds underlying 1 m of recorded gravel is brief (dense, fine sand of varying colour, slightly clayey in the top 60 cm) and attribution to bedrock is not be definitive. Due to the paucity of data for Terrace 9 the borehole remains in the long profile to be indicative only of the possible upstream ground level of the terrace.

Terrace 10

Borehole SZ19 SW137 (Figure 6.14, note 11) falls within the envelope of Terrace 8 at the downstream end of the River Stour. The boreholes' location at the edge of the mapped terrace along with uncertainty in the fluvial origin of the 46 cm deposit of 'yellow sand and rounded gravel' led to the borehole being excluded from long profile projections. Borehole SZ09 NE156 (Figure 6.14, note 12) would appear to be altitudinally more consistent with Terrace 8. Geographically its location would indicate a previously unrecognised stretch of Terrace 8, laterally consistent with Terrace 8 deposits both upstream and downstream. Further upstream at Merley, borehole SZ09 NW27 (Figure 6.14, note 13) is located at the front edge of a Terrace 10 deposit less than 60 m southwest of a deposit mapped as Terrace 8, with the latter's ground level and bedrock recorded ~8 to 5 m lower. In long profile the borehole projects between the levels of Terraces 10 and 8, appearing to represent a previously unrecognised stretch of Terrace 9, laterally equivalent to Terrace 9 as mapped downstream.

Terrace 11

Terrace 11, which is mapped by the BGS as a handful of small deposits in a discontinuous scatter as described above, is not represented in the available borehole record of River Stour terraces.

Terrace 12

Borehole SZ09 SE53A (Figure 6.14, note 14) at Knighton Heath industrial estate is located in Terrace 12, close to the mapped transition to Terrace 13a. Altitudinally the borehole projects closer to Terrace 13a, with ground level between 3 to 5 m higher than Terrace 12 deposits further upstream. Bedrock level is however low for Terrace

13a as recorded less than 1 km upstream, which may indicate the presence of the terrace bluff.

Terrace 13a

A group of 12 boreholes (Figure 6.14, note 15) in a unit mapped as Terrace 13b transitioning to 13a record ground level between 62 to 68 m and bedrock around 60 to 63 m. An examination of the long profile produced (Figure 6.19) shows little differentiation in the ground and bedrock levels of the two terraces. The profile may be showing the edge of Terrace 13b degrading down to Terrace 13a but there is not enough data to be confident in that ascertain. When comparing ground and bedrock altitudes with those of Terrace 13b as mapped upstream at Corfe Mullen (see below), it would appear that the 12 borehole records are more consistent with Terrace 13a. Of those 12 records borehole SZ09NW277 appears geographically and altitudinally to be on an eroded terrace edge and as such is excluded from long profile projections.

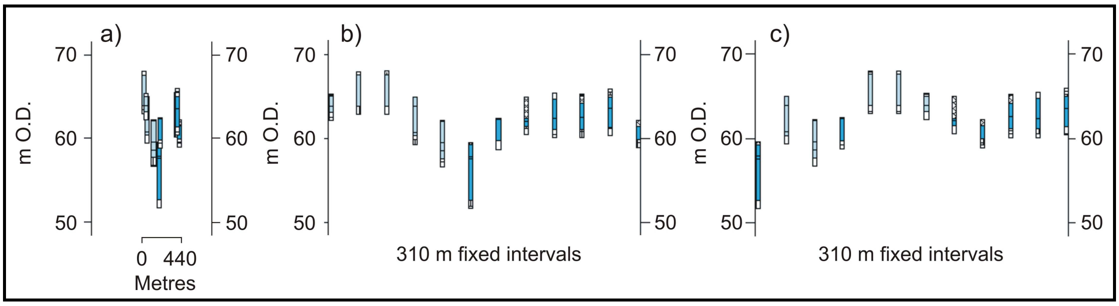


Figure 6.19. Long profile and cross section projections of Terraces 13a and 13b of the River Stour. a) Detail of the Terrace 13b to 13a transition; b) Borehole to borehole profile of records shown in a); c) back to front cross section of Terrace 13b to 13a transition. Profile projected along N120°E with distance measured from zero at SZ 03968 97528.

Terrace 13b

Upstream Terrace 13b is represented in the available borehole record by three closely spaced logs in the Corfe Mullen area, which project to a distinct level to Terrace 13b as mapped downstream. At Corfe Hills ground level is recorded as 77 m O.D. in each borehole, with bedrock ranging between 73.2 m and 74.2 m O.D. They are the only borehole records in Terrace 13b after reassigning those to Terrace 13a as discussed above.

Table 6.4. The available borehole record of the Test valley used in this study. Key to mapping columns: BGS: Bristow *et al*. (1991); A./G.: Allen and Gibbard (1993); W. *et al*.: Westaway *et al*. (2006); SRP: Stratigraphy proposed by this study; Key to terrace nomenclature: EP Ensbury Park; KL Knighton Lodge; OM Old Milton; SB Stanswood Bay; SP Setley Plain; SW Sway; TF Taddiford Farm; WS West Southbourne.

							Previous mapping			
Reference	East.	North.	River	GL	Gr Th.	Bd Ht	BGS	A./G.	W. *et al.*	Revised terrace scheme
SU00SE197	406460	100110	Stour	33.90	1.40	30.30	8	KL	S8	Terrace 8
SY99NE25	399810	096650	Stour	77.00	2.80	73.20	13	SW	S13b	Terrace 13b
SY99NE26	399700	096690	Stour	77.00	1.48	74.20	13	SW	S13b	Terrace 13b
SY99NE27	399660	096740	Stour	77.00	3.17	73.30	13	SW	S13b	Terrace 13b
SZ09NE115	406460	099960	Stour	33.30	4.30	28.50	8	KL	S8	Terrace 8
SZ09NE156	408900	095300	Stour	30.48	5.79	24.69	10	EP	S10	Terrace 8
SZ09NE163	405050	097210	Stour	22.68	1.83	20.39	8	KL	S8	Terrace 1-7
SZ09NE164	405330	097090	Stour	22.36	2.97	18.85	8	KL	S8	Terrace 1-7
SZ09NW114	402690	098330	Stour	28.00	2.51	24.95	8	KL	S8	Terrace 1-7
SZ09NW124	402570	098060	Stour	40.00	0.95	36.00	9	WS	S9	Terrace 10
SZ09NW21	400930	098930	Stour	28.20	2.30	23.70	8	KL	S8	Terrace 1-7
SZ09NW256	404290	096680	Stour	40.00	3.50	36.50	8	KL	S8	Terrace 10
SZ09NW27	401560	098550	Stour	40.35	5.50	34.35	10	EP	S10	Terrace 9
SZ09NW277	404000	095050	Stour	59.57	1.40	52.67	13	TP	S13a	None
SZ09NW278	404040	095090	Stour	62.46	2.60	59.76	13	TP	S13a	Terrace 13a
SZ09NW279	403940	095140	Stour	62.18	2.50	57.68	13	SW	S13b	Terrace 13a
SZ09NW281	403810	095260	Stour	68.05	3.66	63.94	13	SW	S13b	Terrace 13a
SZ09NW287	403860	096150	Stour	57.03	2.44	54.44	12	SP	S12	Terrace 12
SZ09NW29	401660	098610	Stour	35.40	2.50	29.90	8	KL	S8	Terrace 8
SZ09NW299	403810	095150	Stour	65.02	4.65	60.37	13	SW	S13b	Terrace 13a
SZ09NW30	401710	098650	Stour	33.20	3.30	29.40	8	KL	S8	Terrace 8
SZ09NW304	403850	096250	Stour	56.05	1.22	54.23	12	SP	S12	Terrace 12
SZ09NW306	403970	096610	Stour	38.24	0.30	37.55	8	KL	S8	Terrace 10
SZ09NW33	401730	098670	Stour	32.75	2.50	29.10	8	KL	S8	Terrace 8
SZ09NW361	400570	099050	Stour	24.38	2.13	21.33	8	KL	S8	Terrace 1-7
SZ09NW383	402070	098700	Stour	31.00	3.40	27.60	8	KL	S8	Terrace 8

Reference	East.	North.	River	GL	Gr Th.	Bd Ht	B G S	A./G.	W. *et al.*	Revised terrace scheme
							Previous mapping			
SZ09NW384	401390	097920	Stour	46.00	2.80	43.20	10	EP	S10	Terrace 10
SZ09NW385	400980	098230	Stour	47.00	3.30	43.70	10	EP	S10	Terrace 10
SZ09NW394	404130	096540	Stour	41.30	3.65	37.05	8	KL	S8	Terrace 10
SZ09NW400	404890	097300	Stour	24.60	1.00	22.70	8	KL	S8	Terrace 1-7
SZ09NW407	402980	096400	Stour	55.00	5.50	49.50	12	SP	S12	Terrace 12
SZ09NW445	404440	095210	Stour	65.50	3.70	61.10	13	TP	S13a	Terrace 13a
SZ09NW446	404440	095180	Stour	65.30	3.10	61.10	13	TP	S13a	Terrace 13a
SZ09NW447	404410	095170	Stour	65.00	0.60	61.50	13	TP	S13a	Terrace 13a
SZ09NW448	404460	095150	Stour	62.20	1.60	59.90	13	TP	S13a	Terrace 13a
SZ09NW449	404480	095260	Stour	66.00	3.60	61.40	13	TP	S13a	Terrace 13a
SZ09NW464	403810	095250	Stour	68.06	3.66	63.95	13	SW	S13b	Terrace 13a
SZ09NW470	403850	096150	Stour	57.03	2.44	54.41	12	SP	S12	Terrace 12
SZ09NW481	403890	095350	Stour	65.35	1.83	63.22	13	SW	S13b	Terrace 13a
SZ09NW484	403790	096270	Stour	56.05	1.22	54.22	12	SP	S12	Terrace 12
SZ09SE137	408290	091070	Solent	36.00	4.27	31.73	10	TF	S10	Terrace 10
SZ09SE141	409430	091860	Solent	38.30	3.50	34.30	10	TF	S10	Terrace 10
SZ09SE142	409440	091830	Solent	38.30	3.50	34.30	10	TF	S10	Terrace 10
SZ09SE143	409460	091800	Solent	38.40	3.30	34.40	10	TF	S10	Terrace 10
SZ09SE144	409420	091790	Solent	37.00	2.80	33.20	10	TF	S10	Terrace 10
SZ09SE145	409590	091830	Solent	37.70	3.00	33.70	10	TF	S10	Terrace 10
SZ09SE148	409890	091620	Solent	35.70	4.00	30.70	10	TF	S10	Terrace 10
SZ09SE149	409920	091410	Solent	36.90	5.00	31.40	10	TF	S10	Terrace 10
SZ09SE150	409940	091390	Solent	37.00	5.50	31.50	10	TF	S10	Terrace 10
SZ09SE156	408750	091600	Solent	37.72	2.50	34.12	10	TF	S10	Terrace 10
SZ09SE159	408800	091610	Solent	37.10	2.30	33.30	10	TF	S10	Terrace 10
SZ09SE160	408850	091580	Solent	34.69	1.40	32.99	10	TF	S10	Terrace 10
SZ09SE181	408010	094270	Stour	37.85	5.80	30.75	10	EP	S10	Terrace 10
SZ09SE183	408040	093500	Stour	38.56	1.30	36.96	11	OM	S11	Terrace 10

Reference	East.	North.	River	GL	Gr Th.	Bd Ht	Previous mapping BGS	A./G.	W. *et al.*	Revised terrace scheme
SZ09SE2	405310	093560	Solent	53.00	0.91	52.09	12	SP	S12	Terrace 12
SZ09SE208	405980	091375	Solent	43.48	1.20	41.28	11	OM	S11	Terrace 11
SZ09SE209	406020	091795	Solent	46.56	0.60	45.46	11	OM	S11	Terrace 11
SZ09SE225	406020	091510	Solent	45.95	2.20	42.75	11	OM	S11	Terrace 11
SZ09SE3	405420	093480	Solent	53.00	1.83	51.17	12	SP	S12	Terrace 12
SZ09SE336	407070	092810	Solent	46.20	3.00	42.70	11	OM	S11	Terrace 11
SZ09SE337	406995	092775	Solent	45.40	2.70	42.10	11	OM	S11	Terrace 11
SZ09SE338	407005	092680	Solent	45.40	2.80	42.15	11	OM	S11	Terrace 11
SZ09SE339	406900	092630	Solent	42.50	1.00	40.50	11	OM	S11	Terrace 11
SZ09SE340	406880	092650	Solent	43.20	3.00	40.00	11	OM	S11	Terrace 11
SZ09SE341	406870	092640	Solent	43.80	1.70	41.90	11	OM	S11	Terrace 11
SZ09SE395	407640	090860	Solent	38.00	3.05	33.73	10	TF	S10	Terrace 10
SZ09SE424	408940	094220	Stour	33.53	2.74	30.79	10	EP	S10	Terrace 10
SZ09SE465	407080	093000	Solent	49.20	3.50	45.20	12	SP	S12	Terrace 12
SZ09SE466	407060	092950	Solent	45.00	3.35	40.90	12	SP	S12	Terrace 11
SZ09SE467	407130	092920	Solent	48.30	4.65	43.65	12	SP	S12	Terrace 12
SZ09SE469	407220	093060	Solent	49.20	2.00	46.70	12	SP	S12	Terrace 12
SZ09SE470	407260	093140	Solent	48.90	2.00	46.40	12	SP	S12	Terrace 12
SZ09SE471	407390	093220	Solent	47.70	4.90	42.30	12	SP	S12	Terrace 12
SZ09SE472	407350	093310	Solent	48.70	1.75	46.60	12	SP	S12	Terrace 12
SZ09SE473	407420	093370	Solent	50.60	3.55	46.60	12	SP	S12	Terrace 12
SZ09SE474	407510	093450	Solent	50.80	3.20	47.25	12	SP	S12	Terrace 12
SZ09SE475	407610	093500	Solent	49.60	2.85	46.30	12	SP	S12	Terrace 12
SZ09SE476	407670	093570	Solent	49.80	1.10	48.30	12	SP	S12	Terrace 12
SZ09SE477	407720	093620	Solent	50.50	1.15	49.00	12	SP	S12	Terrace 12
SZ09SE482A	409900	091900	Solent	37.19	3.90	32.89	10	TF	S10	Terrace 10
SZ09SE482B	409900	091900	Solent	37.23	2.20	32.93	10	TF	S10	Terrace 10
SZ09SE482C	409900	091900	Solent	36.72	2.70	33.52	10	TF	S10	Terrace 10

Reference	East.	North.	River	GL	Gr Th.	Bd Ht	BGS	A./G.	W. *et al.*	Revised terrace scheme
							Previous mapping			
SZ09SE482D	409900	091900	Solent	36.96	3.70	33.06	10	TF	S10	Terrace 10
SZ09SE482E	409900	091900	Solent	37.04	3.60	32.84	10	TF	S10	Terrace 10
SZ09SE50	408190	090730	Solent	37.61	3.73	33.42	10	TF	S10	Terrace 10
SZ09SE515	408940	094220	Stour	33.53	2.74	30.79	10	EP	S10	Terrace 10
SZ09SE52	408230	090680	Solent	36.67	1.98	34.23	10	TF	S10	Terrace 10
SZ09SE53A	405400	094970	Stour	60.35	4.11	55.63	12	SP	S12	Terrace 13a
SZ09SE543	408720	091600	Solent	37.72	2.50	34.14	10	TF	S10	Terrace 10
SZ09SE545	408810	091540	Solent	36.56	0.40	34.26	10	TF	S10	Terrace 10
SZ09SE76	407240	090130	Solent	29.14	3.00	25.94	9	SB	S9	Terrace 9
SZ09SE82	408750	091460	Solent	34.75	4.70	29.05	10	TF	S10	Terrace 10
SZ09SE90	408900	092200	Solent	37.00	2.50	33.50	10	TF	S10	Terrace 10
SZ09SW1002	403490	093510	Solent	66.66	3.05	62.70	13	SW	S13b	Terrace 13b
SZ09SW1465	404120	093930	Solent	61.00	1.37	58.71	13	SW	S13b	Terrace 13a
SZ09SW1467	404150	093920	Solent	61.00	1.22	59.63	13	SW	S13b	Terrace 13a
SZ09SW1469	404130	093940	Solent	61.00	1.37	59.32	13	SW	S13b	Terrace 13a
SZ09SW1470	404130	093950	Solent	61.00	0.91	59.78	13	SW	S13b	Terrace 13a
SZ09SW1754	403480	093490	Solent	66.66	3.05	62.70	13	SW	S13b	Terrace 13b
SZ09SW622	403480	093180	Solent	64.00	0.70	61.90	13	SW	S13b	Terrace 13b
SZ19SW137	410710	093940	Stour	24.14	0.46	22.92	10	EP	S10	None
SZ19SW14	410410	092610	Solent	38.25	3.66	33.68	10	TF	S10	Terrace 10
SZ19SW146	410600	092320	Solent	35.90	1.70	33.00	10	TF	S10	Terrace 10
SZ19SW147	410520	092030	Solent	34.35	4.45	29.35	10	TF	S10	Terrace 10
SZ19SW148	410470	091930	Solent	34.70	5.30	27.20	10	TF	S10	Terrace 10
SZ19SW15	410580	092640	Solent	38.05	3.35	33.48	10	TF	S10	Terrace 10
SZ19SW153	411600	092520	Solent	33.30	2.30	31.00	10	TF	S10	Terrace 10
SZ19SW154	411810	091550	Solent	22.50	3.05	14.58	10	TF	S10	None
SZ19SW160	411300	091770	Solent	36.58	3.96	32.62	10	TF	S10	Terrace 10
SZ19SW161	410230	092790	Solent	39.62	2.74	36.27	11	OM	S11	Terrace 10
SZ19SW162	412550	092470	Solent	32.92	4.88	28.04	10	TF	S10	Terrace 10

Reference	East.	North.	River	GL	Gr Th.	Bd Ht	Previous mapping BGS	A./G.	W. *et al.*	Revised terrace scheme
SZ19SW172	410680	092660	Solent	32.60	0.70	31.40	10	TF	S10	Terrace 10
SZ19SW173	410690	092640	Solent	32.10	1.85	29.05	10	TF	S10	Terrace 10
SZ19SW175	410790	092700	Solent	34.70	1.90	32.20	10	TF	S10	Terrace 10
SZ19SW176	410710	092650	Solent	38.30	4.70	29.60	10	TF	S10	Terrace 10
SZ19SW239	410320	091950	Solent	30.48	2.14	28.34	10	TF	S10	Terrace 10
SZ19SW240	411130	092110	Solent	38.40	8.23	29.26	10	TF	S10	Terrace 10
SZ19SW241	411140	092080	Solent	39.01	6.55	31.39	10	TF	S10	Terrace 10
SZ19SW242	411180	092090	Solent	39.01	2.44	36.04	10	TF	S10	Terrace 10
SZ19SW244	410280	092760	Solent	38.40	3.96	34.44	11	OM	S11	Terrace 10
SZ19SW245	410100	092620	Solent	39.32	2.34	36.42	11	OM	S11	Terrace 10
SZ19SW246	410720	092670	Solent	32.31	3.66	28.04	10	TF	S10	Terrace 10
SZ19SW248	411710	093920	Stour	16.23	0.30	15.47	8	KL	S8	None
SZ19SW249	411770	093930	Stour	24.14	0.46	22.92	8	KL	S8	Terrace 8
SZ19SW254	410230	092780	Solent	39.62	2.74	36.27	11	OM	S11	Terrace 10
SZ19SW255	412200	092300	Solent	35.05	3.66	30.78	10	TF	S10	Terrace 10
SZ19SW273	412020	093750	Stour	23.67	3.00	19.97	8	KL	S8	Terrace 8
SZ19SW279	411950	093790	Stour	27.75	1.60	25.65	8	KL	S8	Terrace 8
SZ19SW285	412050	093710	Stour	23.70	1.10	22.10	8	KL	S8	Terrace 8
SZ19SW287	412140	093680	Stour	25.50	2.40	22.50	8	KL	S8	Terrace 8
SZ19SW289	412100	093700	Stour	25.50	1.80	23.30	8	KL	S8	Terrace 8
SZ19SW298	411970	093780	Stour	27.15	3.00	23.45	8	KL	S8	Terrace 8
SZ19SW303	411820	093830	Stour	28.05	2.50	24.95	8	KL	S8	Terrace 8
SZ19SW304	411850	093790	Stour	27.86	3.20	23.96	8	KL	S8	Terrace 8
SZ19SW305	411880	093750	Stour	27.68	2.60	24.28	8	KL	S8	Terrace 8
SZ19SW315	411890	093870	Stour	26.50	0.70	21.90	8	KL	S8	Terrace 8
SZ19SW316	411870	093870	Stour	26.50	1.20	23.50	8	KL	S8	Terrace 8
SZ19SW317	411910	093850	Stour	26.80	0.90	25.00	8	KL	S8	Terrace 8
SZ19SW318	411920	093820	Stour	27.30	0.60	26.00	8	KL	S8	Terrace 8
SZ19SW329	414000	091490	Solent	10.50	3.00	7.00	9	SB	S9	None

Reference	East.	North.	River	GL	Gr Th.	Bd Ht	Previous mapping BGS	A./G.	W. *et al.*	Revised terrace scheme
SZ19SW331	414030	091440	Solent	9.00	3.60	4.70	9	SB	S9	None
SZ19SW60	413310	091890	Solent	27.13	2.44	24.39	9	SB	S9	Terrace 9
SZ19SW66	411940	093630	Stour	27.63	2.14	24.73	8	KL	S8	Terrace 8
SZ19SW7	410450	092000	Solent	35.00	2.90	31.70	10	TF	S10	Terrace 10
SZ19SW70	411940	092050	Solent	34.75	2.43	30.03	10	TF	S10	Terrace 10
SZ19SW71	412230	091820	Solent	34.05	1.37	31.00	10	TF	S10	Terrace 10
SZ19SW73	413240	091730	Solent	31.50	3.35	26.78	10	TF	S10	Terrace 10
SZ19SW75	414610	091540	Solent	28.67	2.13	25.77	9	SB	S9	Terrace 9
SZ19SW93	410600	091550	Solent	36.00	1.30	34.20	10	TF	S10	Terrace 10
SZ19SW94	410600	091550	Solent	36.00	2.50	33.00	10	TF	S10	Terrace 10
SZ19SW95	410600	091550	Solent	36.00	3.80	31.80	10	TF	S10	Terrace 10
SZ19SW96	410600	091550	Solent	36.00	4.60	30.80	10	TF	S10	Terrace 10

CHAPTER SEVEN: GEOCHRONOLOGY

The primary aim of the geochronological element to this study was to produce chronological tie-points for key terraces of the Solent River system. The anticipated antiquity of the terraces of the Solent region, which spans the Pleistocene (Reid 1902; Allen and Gibbard 1993; Gibbard and Preece 1999), and reported issues in previous OSL studies on the sequence (Bates *et al*. 2004, 2010; Briant *et al*. 2006, 2009b and 2009c; Schwenninger *et al.* 2007; Briant *et al*. 2012), led to the development of a rigorous programme of tests in order to assess the ages produced (Chapter 3.3.5). Specific geochronological aims for elements of the study area were as follows: to determine the relationship of the lower Test terraces (as seen at Warsash and Solent Breezes) with the Western Solent region, and to establish the age of the archaeologically important River Test Terrace 3 (aims B and C; Chapter 4.1); and to establish the age of key Western Solent terraces (aim C; Chapter 5.1) in order to evaluate and, where necessary, revise existing chronological tie-points. An improved chronological framework for the region would also contribute to the revised interpretation of the Solent River system stratigraphic sequence (Chapter 8.1) and contextualise the archaeology of the region (Chapter 8.3).

7.1 Site selection

The selection of sites to investigate through OSL dating was primarily based on specific research questions as outlined in Chapters 4, 5 and 6. Previous work in the Western Solent region (Briant *et al*. 2006, 2009b; Schwenninger *et al.* 2007) has produced OSL dates for the Pennington Upper Gravel, Lepe Upper Gravel and Lepe Lower Gravel, and the Stanswood Bay, Taddiford Farm, Tom’s Down and Old Milton terraces. Work in the Test valley (Bates *et al*. 2004, 2010; Briant *et al*. 2012) has also produced OSL age for Terraces 1, 2, 5, 6 and 8 of the River Test. As discussed below confidence is limited in those dates produced above the Stanswood Bay terrace in the Western Solent and above Terrace 2 of the Test (Bates and Briant 2009). The specific issues that were encountered in determining these ages are discussed in Chapter 7.7. With the exception of the Old Milton sample (from Barton on Sea), the previous Western Solent samples were derived from the eastern end of the terrace sequence (at Fawley, Exbury, Stanswood Bay, Lepe and Pennington). As a result, in this study potential sites suitable for OSL dating were sought at the western end of the Western Solent terrace sequence, between Barton on Sea and Milford on Sea, to expand the dataset and allow comparison of ages produced at either end of terrace units (as mapped by Allen and Gibbard 1993; Westaway *et al*. 2006). In the Test valley the key terrace lacking chronological data is Terrace 3, as discussed in Chapter 2.4. Efforts were therefore focused on locating potential sites on this terrace level.

An additional consideration was access to exposed fluvial sediments or sites where excavation would potentially reveal suitable sand units for OSL dating. Locations were sought based on the known locations of terrace gravels and the likelihood of finding associated fluvial sand beds. Locations were also sought that provided the possibility for the excavation of suitable sediments by hand, due to the cost and time implications of more extensive mechanical excavation. This approach meant that more locations could be assessed relatively quickly, while limiting potential target areas to coastal exposures and former quarrying sites that had not been extensively refilled or developed. Locations were available in the Western Solent study area due to coastal erosion by the modern Solent, which exposes the aforementioned sequence of fluvial sands and gravels in cliffs between Barton on Sea and Milford on Sea. In the Test valley area, former gravel quarries were located which provided access to *in situ* fluvial sands and gravels. Samples that had previously been collected from Terrace 2 of the River Test at Brownwich Lane were also made available for dating (Chapter 4.4). Sites were chosen to maximise the suitability of the sediment for OSL as detailed in Chapter 3.3.2 (Methods).

The in-field collection protocols of samples for OSL dating were employed as detailed in Chapter 3.3.2 (Methods). *In situ* gamma spectrometry was carried out at each site, with the exception of the previously collected samples from Brownwich Lane (Test Terrace 2) from which gamma spectrometry data was also made available. Each sample was also analysed by inductively-coupled plasma-mass spectrometry (ICP-MS) to determine uranium (^{238}U), potassium (^{20}K) and thorium (^{232}Th) concentrations.

Table 7.1. OSL sample summary. Additional samples HOR311-02, ROO11-02, WAC10-01 and WAC10-02 were not processed as discussed below. Terrace attributions as per the mapping schemes of Allen and Gibbard (1993) and Westaway *et al.* (2006) are shown alongside the revised stratigraphy proposed in Chapters 4 and 5.

Sample code	Site name	G.S.	Easting	Northing	Region	Allen & Gibbard	Mapping Westaway *et al.*	Proposed stratigraphy
HAP10-02Fs	Hamble Park	SU	450641	106051	Test	Terrace 3	Belbin (T4)	Terrace 3
HAP10-02Qz	Hamble Park	SU	450641	106051	Test	Terrace 3	Belbin (T4)	Terrace 3
HAP10-03Fs	Hamble Park	SU	450641	106051	Test	Terrace 3	Belbin (T4)	Terrace 3
HAP10-03Qz	Hamble Park	SU	450641	106051	Test	Terrace 3	Belbin (T4)	Terrace 3
WAC10-03Fs	Warsash Common	SU	450647	105881	Test	Terrace 3	Belbin (T4)	Terrace 3
WAC10-03Qz	Warsash Common	SU	450647	105881	Test	Terrace 3	Belbin (T4)	Terrace 3
BRW08-02Fs	Brownwich Lane	SU	451316	103566	Test	Terrace 2	Hamble (T2)	Terrace 2
BRW08-02Qz	Brownwich Lane	SU	451316	103566	Test	Terrace 2	Hamble (T2)	Terrace 2
BRW08-03Fs	Brownwich Lane	SU	451239	103596	Test	Terrace 2	Hamble (T2)	Terrace 2
BRW08-03Qz	Brownwich Lane	SU	451239	103596	Test	Terrace 2	Hamble (T2)	Terrace 2
HOR311-02Qz	Hordle Cliff 3 Taddiford Farm terrace	SZ	425848	092450	Western Solent	Taddiford Farm	Downton	Stanswood Bay
HOR311-04Fs	Hordle Cliff 3 Taddiford Farm terrace	SZ	425843	092452	Western Solent	Taddiford Farm	Downton	Stanswood Bay
HOR311-04Qz	Hordle Cliff 3 Taddiford Farm terrace	SZ	425843	092452	Western Solent	Taddiford Farm	Downton	Stanswood Bay
HOR111-02Fs	Hordle Cliff 1 Stanswood Bay terrace	SZ	426702	092139	Western Solent	Stanswood Bay	Stanswood Bay	Stanswood Bay
HOR111-02Qz	Hordle Cliff 1 Stanswood Bay terrace	SZ	426702	092139	Western Solent	Stanswood Bay	Stanswood Bay	Stanswood Bay
HOR111-04Fs	Hordle Cliff 1 Stanswood Bay terrace	SZ	426700	092139	Western Solent	Stanswood Bay	Stanswood Bay	Stanswood Bay
HOR111-04Qz	Hordle Cliff 1 Stanswood Bay terrace	SZ	426700	092139	Western Solent	Stanswood Bay	Stanswood Bay	Stanswood Bay
HOR211-06Fs	Hordle Cliff 2 Stanswood Bay terrace	SZ	426392	092239	Western Solent	Stanswood Bay	Stanswood Bay	Stanswood Bay
HOR211-06Qz	Hordle Cliff 2 Stanswood Bay terrace	SZ	426392	092239	Western Solent	Stanswood Bay	Stanswood Bay	Stanswood Bay
ROO11-02Qz	Rook Cliff	SZ	428172	091619	Western Solent	Milford on Sea	Milford on Sea	Milford on Sea

Samples were taken at seven localities across the Solent study area (Figure 7.1, Table 7.1), representing ten distinct sand units. In total five fluvial terrace levels (as mapped by Allen and Gibbard 1993; Westaway *et al*. 2006) were sampled for OSL dating. In the Test region, sediments were sampled at Brownwich Lane (BRW08-02 & 03) (near Solent Breezes), Hamble Park (HAP10-02 & 03) and Warsash Common (WAC10-03) (both at Warsash). In the Western Solent region sediments were sampled at Rook Cliff (ROO11-02) (Milford on Sea) and three sites at Hordle Cliff (HOR111-02 & 04; HOR211-06; HOR311-02 & 04) (southeast of Barton on Sea). The terrace attributions in the schemes of Allen and Gibbard (1993), Westaway *et al*. (2006) and those proposed by this study are shown in Table 7.1. Replicate samples were collected at each site.

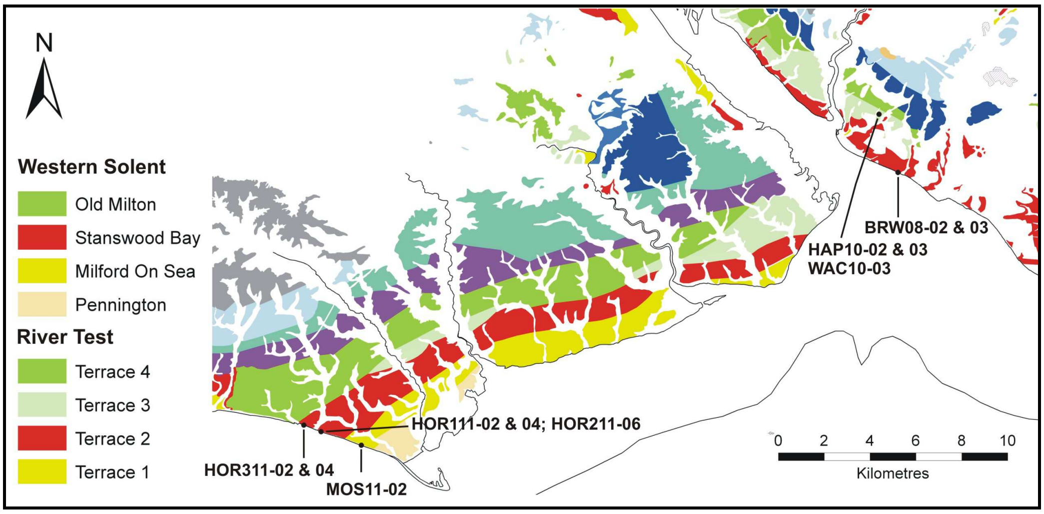


Figure 7.1. Location map of samples taken for OSL dating. Site names are as in Table 7.1.

7.2 Sample preparation

Samples were prepared using the quartz separation and feldspar separation protocols as detailed in Chapter 3.3.3 (Methods), with the majority proving unproblematic. However after initial processing and sample preparation, the ROO11-02 and HOR311-02 samples yielded insufficient feldspar to provide enough material for analysis. Both samples were therefore limited to analysis of their quartz component, which did yield sufficient material. A visual inspection of samples WAC10-01 and 02 in the laboratory prior to preparation showed that they contained numerous outsized pebble clasts which had not been apparent during sample collection on site. If these inclusions contained a greater concentration of highly radioactive emitters (e.g.

zircons) they would not be detected during dose rate determination, but would have a pronounced effect on the micro-dosimetry of individual grains and grain clusters and therefore the overall aliquot. Due to the possibility of introduced radioactive elements from inclusions affecting the dose rate calculation the samples were not taken any further.

7.3 Tests

Table 7.2 lists the results of those tests as applied to the samples collected for the study. Figures 7.2, 7.3 and 7.4 provide examples of results obtained by the application of DRT, PHT and TTT protocols. Six of the twenty samples passed all three test stages and were deemed suitable for the application of the SAR protocol in order to produce dates.

Table 7.2. Results of the test procedures applied to samples in the study. The Dose Recovery Test (DRT) indicates preheat temperatures in the test SAR applied that resulted in accurate recovery of a given dose; The Preheat Test (PHT) indicates the thermal pre-treatment that removes the unstable signal component in an artificially induced signal; The Thermal Transfer Test (TTT) detects thermal transfer of electrons from light-insensitive to light-sensitive traps. The final column indicates the suitability of a sample for age calculation and the appropriate preheat temperature to be used in the SAR protocol for that sample.

Sample code	DRT (°C)	PHT (°C)	TTT	Status
HAP10-02Fs	None	None	Increasing with PHT	Unsuitable
HAP10-02Qz	270°	270°	Some thermal transfer at 290° C	Date at 270°
HAP10-03Fs	250°, 270°	None	Increasing with PHT	Unsuitable
HAP10-03Qz	270°	270°	No thermal transfer	Date at 270°
WAC10-03Fs	230-290°	230-250°	Some thermal transfer increasing with PHT	Date at 230°
WAC10-03Qz	None	None	No thermal transfer	Unsuitable
BRW08-02Fs	None	None	Some thermal transfer at 290° C	Unsuitable
BRW08-02Qz	270°, 290°	270-290°	No thermal transfer	Date at 270°
BRW08-03Fs	None	None	No thermal transfer	Unsuitable
BRW08-03Qz	230° (weak)	None	No thermal transfer	Unsuitable
HOR311-02Qz	None	None	No thermal transfer	Unsuitable
HOR311-04Fs	None	None	No thermal transfer	Unsuitable
HOR311-04Qz	None	None	No thermal transfer	Unsuitable
HOR111-02Fs	290° (weak)	None	Some thermal transfer at 290° C	Unsuitable
HOR111-02Qz	None	270-290° (weak)	No thermal transfer	Unsuitable
HOR111-04Fs	250°, 290°	270-290°	No thermal transfer	Date at 290°
HOR111-04Qz	(230°), 290°	None	No thermal transfer	Unsuitable
HOR211-06Fs	230-270°	230-270°	Some thermal transfer at 310° C	Date at 230°
HOR211-06Qz	None	None	No thermal transfer	Unsuitable
ROO11-02Qz	230° (weak)	230-250° (weak)	No thermal transfer	Unsuitable

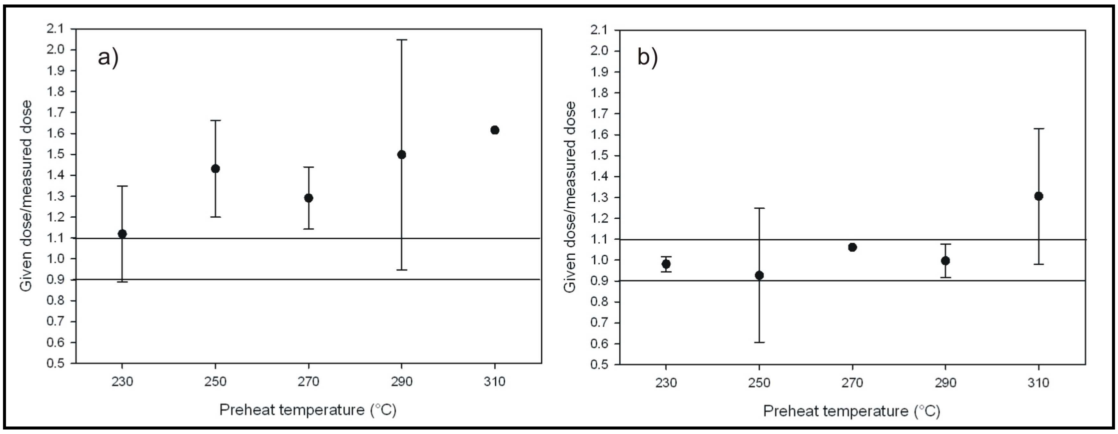


Figure 7.2. Examples of the dose recovery test. Sample WAC10-03Qz (a) failed to accurately recover a given dose at any preheat temperature applied, with an accumulated signal apparent as the sample is subjected to increased preheat temperatures. WAC10-03Fs (b) achieved a given dose/measured dose ratio close to 1.0 for preheat temperatures 230-290° C.

The dose recovery tests (Figure 7.2) showed robust SAR behaviour in just >50% of cases, as nine of the twenty samples failed to accurately recover the given dose (e.g. WAC10-03Qz, Figure 7.2a). The remainder of samples showed a varied response to the dose recovery test, indicating accurate recovery at some temperature ranges but not others (e.g. WAC10-03Fs, Figure 7.2b).

More than half of samples failed to produce clear plateaus in preheat temperatures during the preheat tests (e.g. figure 7.3 c & d). Figure 7.3 (a & b) shows examples of potential plateaus in samples HOR211-06Fs and HAP10-03Qz, which still may be problematic as the former is based on two temperatures (250° C and 270° C) from single aliquots and the latter involves a large error margin at 250° C.

The majority of samples performed well in the thermal transfer tests, showing no increase in apparent palaeodose as the preheat temperature applied increased. However, samples HAP10-02Fs (Figure 7.4a) and HAP10-03Fs for example show a signal thermally induced from light-insensitive (but heat-sensitive) to light-sensitive traps. Samples HAP10-02Qz, WAC10-03Fs and HOR211-06Fs indicated minor thermal transfer at and above specific temperatures which informed the preheat temperature chosen for the SAR protocol (270° C, 230° C and 230° C respectively). The remainder of the samples showed no thermal transfer occurring (e.g. BRW08-03Qz, Figure 7.4b).

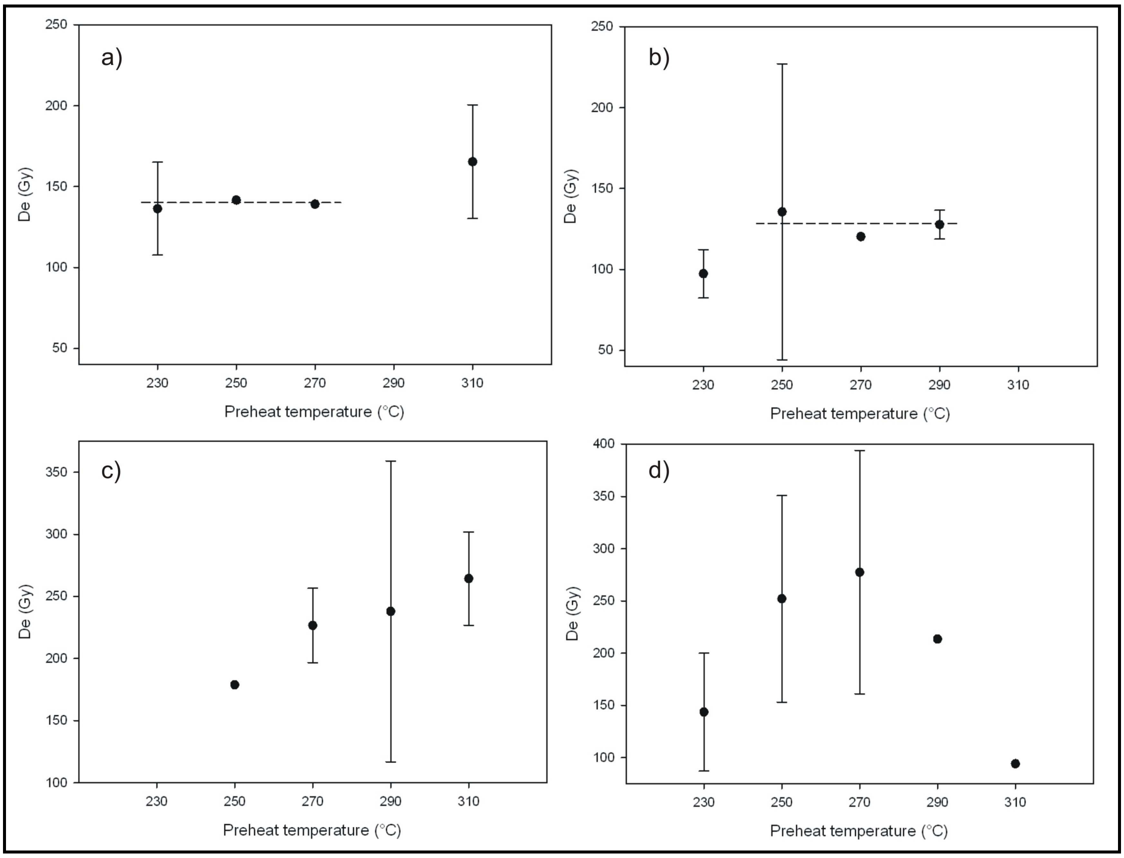


Figure 7.3. Preheat plateaus as detected in samples HOR211-06Fs (a) and HAP10-03Qz (b) indicate preheat temperatures which remove unstable signal components. Twelve of the twenty samples collected (e.g. (c) HAP10-02Fs and (d) BRW08-03Qz) failed to identify thermal pre-treatments that emptied thermally unstable electron traps, as indicated by the more varied signal produced by the same dose applied at preheat temperatures of 230°, 250°, 270°, 290° and 310° C.

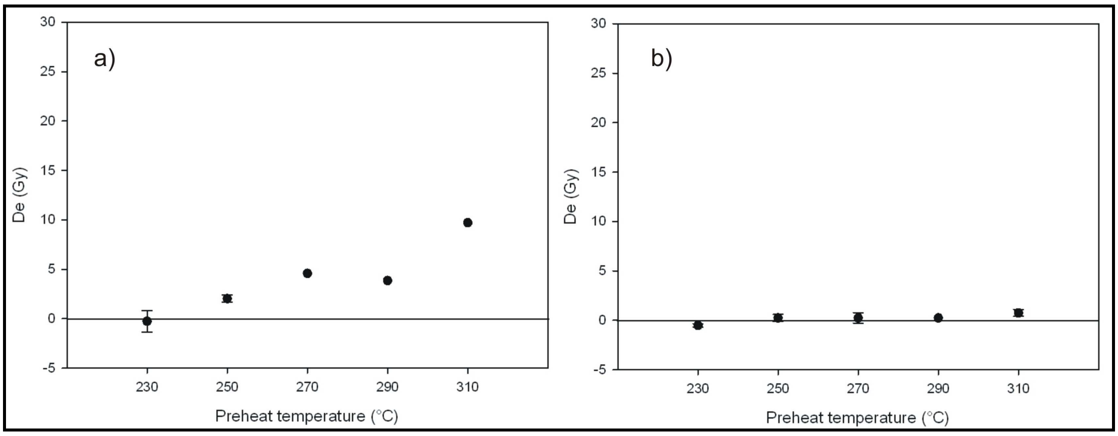


Figure 7.4. Results from two Thermal Transfer Tests. A thermally transferred signal detected in (a) sample HAP10-02Fs. No such signal is seen in (b) sample BRW08-03Qz. Each sample had its natural signal erased prior to the application of preheat temperatures and when measured should produce a signal of zero Gy.

The overall performance of samples subjected to dose recovery, preheat and thermal transfer tests was generally poor and the majority (14 of 20) were therefore not suitable for OSL dating. However, samples HAP10-02Qz, HAP10-03Qz, BRW08-

02Qz, WAC10-03Fs, HOR211-06Fs and HOR111-04Fs performed adequately enough (Table 7.2) and can be deemed to fulfil the basic pre-requisites of the SAR protocol (Wintle and Murray 2006). These six samples were therefore measured using a SAR protocol (Murray and Wintle 2000, 2003; Wintle and Murray 2006) in order to determine equivalent doses (D_es). The accepted samples (Table 7.2, above) show that of the seven individual sites investigated, five (Hamble Park, Warsash Common and Brownwich Lane in the Test Valley and Hordle Cliff sites 1 and 2 in the Western Solent) produced datable sediments. Of the accepted samples, three were Qz and three were Fs. Unfortunately no individual sediment yielded accepted samples of both minerals, therefore there was no opportunity to check ages produced by Qz and Fs recovered from the same bed.

7.4 D_e determination

Samples were measured using the protocols outlined in Chapter 3.3.4 (Methods) in order to determine D_es. Two SAR sequences of 24 aliquots were carried out on each sample. Unfortunately the final batch measured (the second SAR protocols applied to samples WAC10-03Fs, HOR211-06Fs and HOR111-04Fs) were affected by technical problems with the Risø reader used, issues which were not detected in time to repeat measurement. As a result samples WAC10-03Fs, HOR211-06Fs and HOR111-04Fs only have data available from a single 24 aliquot SAR sequence.

The performance of each aliquot measured was assessed relative to a number of criteria before they could be considered to contribute to the determination of a sample's D_e (see Table 7.3 below). Firstly aliquots which produced a recycling ratio of greater than ±15% were rejected, with 61% (132 of 216) meeting the criteria for acceptance. The ±15% cut off point exceeds that of ±10% suggested by Murray and Wintle (2000). However, as there is no correlation between the D_e and the recycling ratios of aliquots in each sample (Figure 7.5) a higher recycling ratio cut off point does not introduce any systemic bias (Frank Preusser, pers. comm.). It was therefore reasonable to use a higher recycling ratio cut off point. It was also deemed reasonable to increase the threshold due to the more complex issues encountered during this study. Overall the majority of aliquots used in the final age calculations (61 of 78;

78%, see below) did in fact conform to a ±10% threshold, with 17 of 78 aliquots (22%) falling in the ±15% range.

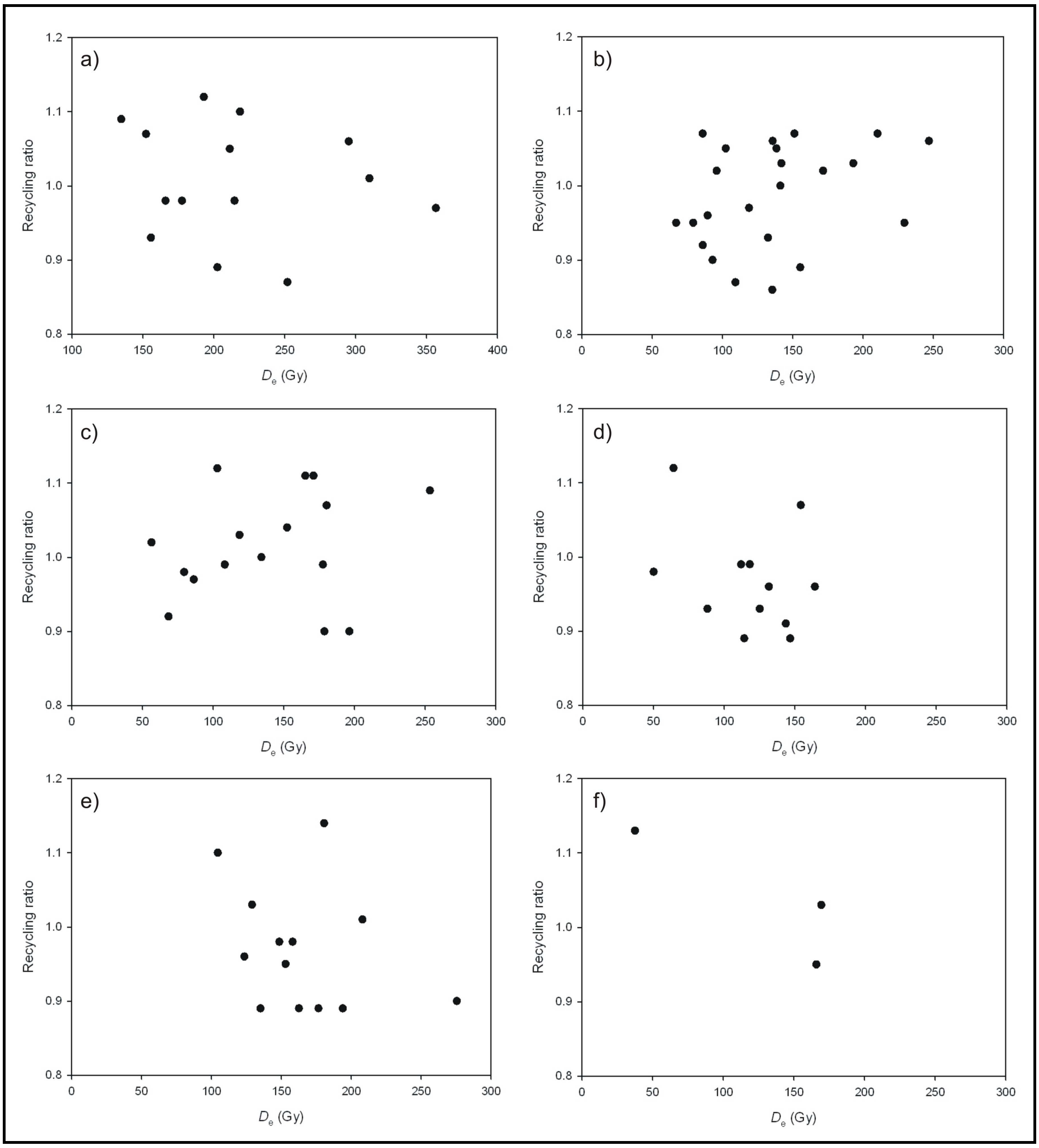


Figure 7.5. Sensitivity change, expressed as the recycling ratio against recovered D_e (Gy), exhibited in samples (a) HAP10-02Qz, (b) HAP10-03Qz, (c) BRW08-02Qz, (d) WAC10-03Fs, (e) HOR211-06Fs and (f) HOR111-04Fs. No correlation can be detected between the D_e (Gy) and the recycling ratio of samples.

Curve fitting was carried out using exponential or exponential and linear fits, with preference given to the method which produced the lower average error in the fit. Curve fitting was generally unproblematic, with only 12 of 132 aliquots (9.01%) that passed the recycling ratio criteria rejected on the criterion of producing a viable regeneration curve (Figure 7.6a). Issues primarily related to apparent saturation of electron traps within grains, where the latent luminescence signal reached the point of filling all available traps over time, in effect ceasing accumulation of a signal and therefore not recording depositional time (Figure 7.6b).

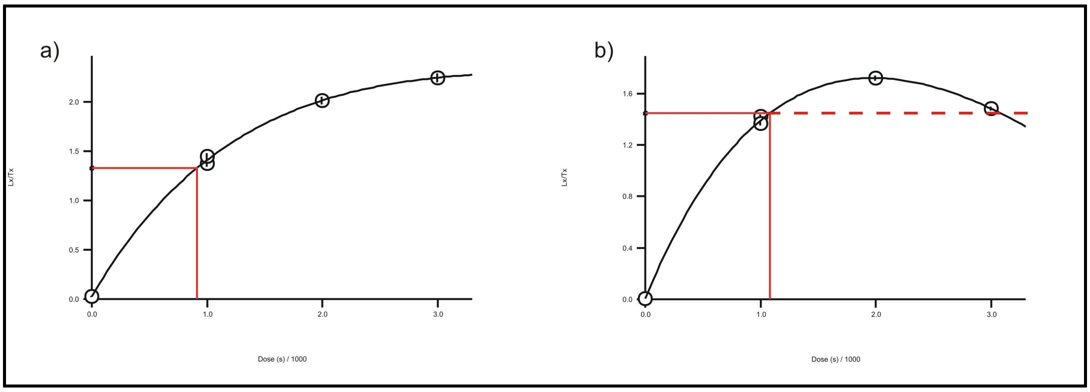


Figure 7.6. Examples of the curve fitting of sample HAP10-03Qz aliquot 3 (a) and sample HAP10-03Qz aliquot 2 (b). HAP10-03Qz aliquot 3 (a) shows a good fit of the growth curve, with an average error of 0.0099. HAP10-03Qz aliquot 2 (b) shows a similarly good fit of the curve to regeneration points, however the sample appears close to saturation in the trap response, indicated by a reduced signal produced by regenerative dose 3 when compared to regenerative dose 2. HAP10-03Qz aliquot 2 was therefore rejected.

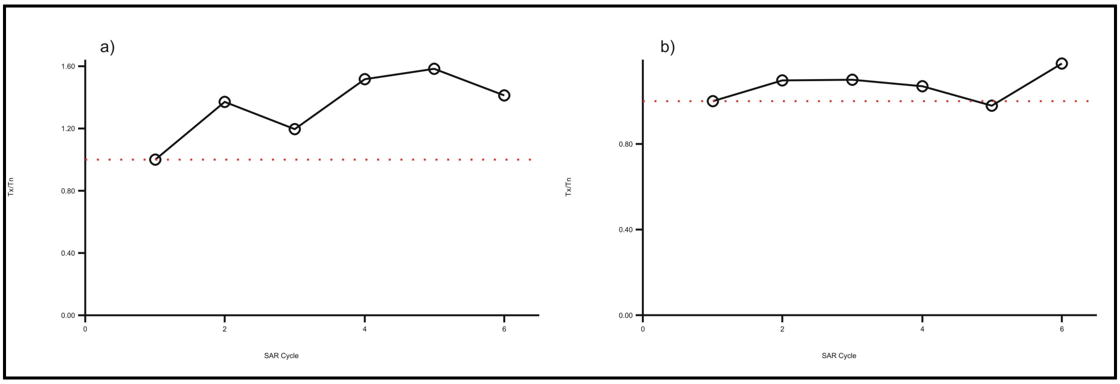


Figure 7.7. Examples of the response of sample BRW08-02Qz aliquot 1 (a) and sample BRW08-02Qz aliquot 10 (b) to the application of the test dose during the SAR protocol. BRW08-02Qz aliquot 1 (a) shows a high degree of sensitivity change, with *T*x/*T*n values of 1.0, 1.37, 1.19, 1.51, 1.58 and 1.41. BRW08-02Qz aliquot 10 (b) shows less sensitivity change occurring with *T*x/*T*n values of 1.0, 1.09, 1.1, 1.07, 0.98 and 1.17.

As a final measure of the success of the SAR protocol to determine the D_e of a sample, the response of each aliquot to a fixed test dose (*T*) was examined. This response shows sensitivity changes that may have been present during the measurement of the main OSL signal (*L*) within a regenerative dose procedure such as the SAR protocol. Studies have shown that sensitivity changes can reach a factor of two when sedimentary grains are heated (Wintle and Murray 2000). To reduce the possible impact of sensitivity change a limit of ±50% was employed, with aliquots showing more than 50% change being rejected. Under this criterion 81 of the remaining 120 aliquots (67.5%) were accepted. Figure 7.7 shows examples of the problems encountered.

It was hoped that the samples processed would each yield, after the three test stages applied, a minimum of 24 aliquots suitable for producing OSL ages for each sample. This did not occur. Table 7.3 details the success rate of aliquots during the SAR protocol in regard to their recycling ratio, curve fitting and sensitivity correction. The final column in Table 7.3 indicates how many aliquots would have been required initially for each sample to have yielded a sample size of 24 aliquots that passed the suite of test stages applied. As a theoretical exercise it underlines the poor performance of samples taken from the Middle Pleistocene fluvial deposits of the Test Valley and the Western Solent for this study, which is out of line with OSL studies in other regions where a similarly rigorous testing programme has been carried out (e.g. Wallinga 2002).

Table 7.3. Number (and percentage) of aliquots which passed an assessment of the recycling test, curve fitting and sensitivity change within a regenerative cycle test for each sample. The final column indicates the number of aliquots required to provide a final sample size of 24 aliquots based on those success rates.

Sample code	Total aliquots measured	Passed recycling test	% of total aliquots	Passed curve fitting	% of total aliquots	Passed sensitivity correction/ Final sample size	% of total aliquots	Theoretical sample size required
HAP10-02Qz	48	28	58.33	24	50.00	14	29.17	82
HAP10-03Qz	48	37	77.08	32	66.67	23	47.92	50
BRW08-02Qz	48	32	66.67	30	62.50	16	33.33	72
WAC10-03Fs	24	13	54.17	13	54.17	12	50.00	48
HOR211-06Fs	24	16	66.67	16	66.67	13	54.17	44
HOR111-04Fs	24	6	25.00	5	20.83	3	12.50	192

Figure 7.8 shows the distribution of D_es produced by those aliquots which were deemed to have passed the various test stages applied during the analysis of the luminescence properties of samples. Sample HOR111-04Fs was rejected at this point as the sample only produced 3 accepted aliquots, insufficient to be confident in any final D_e calculation.

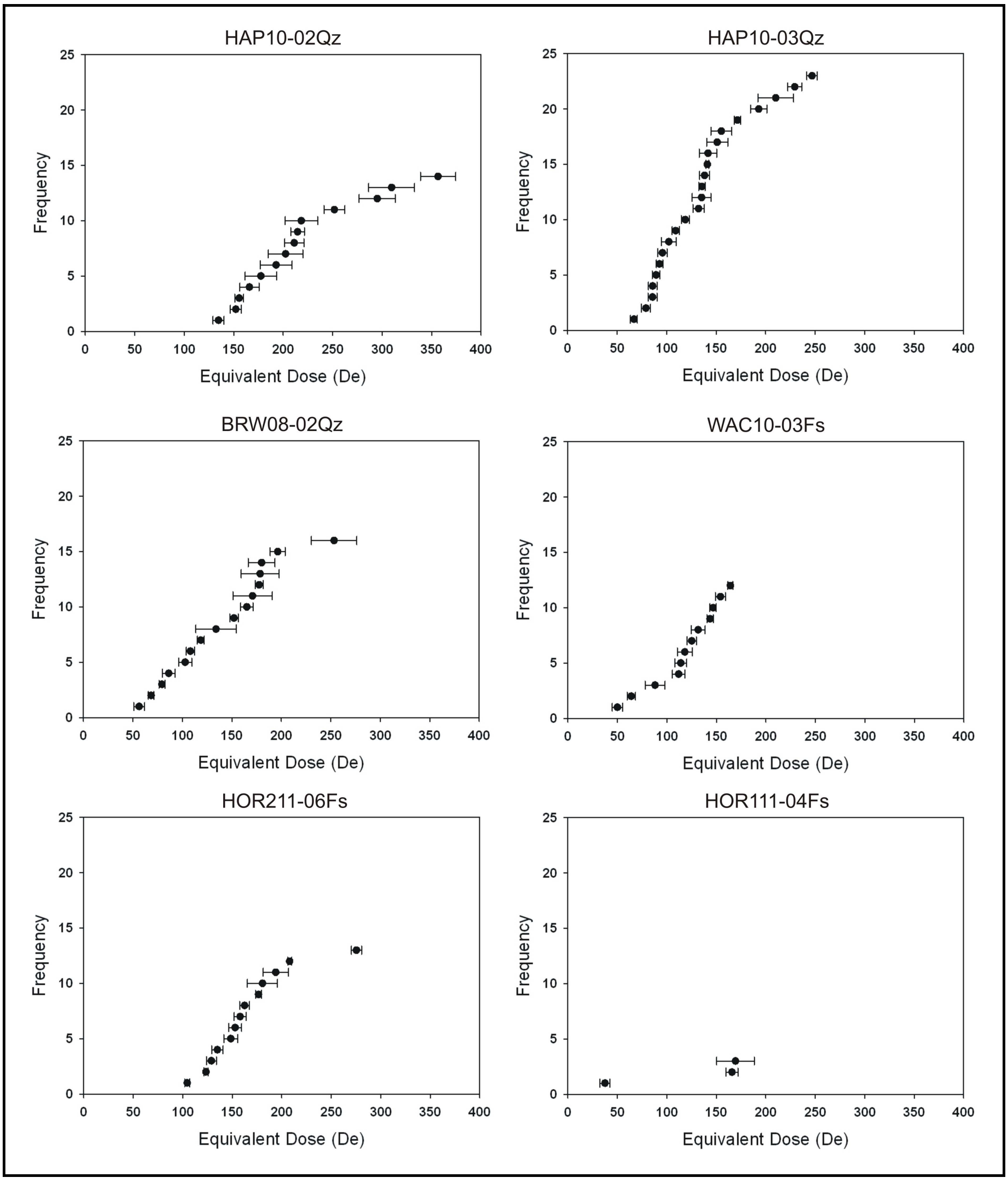


Figure 7.8. D_e distribution of aliquots that passed the recycling, curve fitting and sensitivity correction test stages.

7.5 Age calculation

D_es produced by samples HAP10-02Qz, HAP10-03Qz, BRW08-02Qz, WAC10-03Fs and HOR211-06Fs were used to produce age calculations as seen in Table 7.4. Dose rates (D (Gy ka^{-1})) were calculated using ^{20}K, ^{238}U and ^{232}Th concentrations provided by ICP-MS analysis carried out on samples by the Scottish Universities Environmental Research Centre (SUERC). Results from the *in situ* gamma spectrometer measurements of the radiation dose provided to samples are not currently available due to technical problems with the instrument. Cosmic dose rates and the effects of water content were calculated from standard sedimentary data from site locations (see Chapter 3.3.4).

The use of isotope concentration data obtained by ICP-MS is not without problems. The method analyses a subsample of sediment recovered from the location of OSL samples taken in a sedimentary unit. 30-50 g of sediment per sample was sent for analysis, from which 10g was processed, with 0.1 g subsequently dissolved and analysed by ICP-MS. It is therefore difficult to assess how representative the sample analysed is in terms of the sediment body as a whole. As discussed in Chapter 3.3.2 (Methods), gamma radiation in particular travels up to 0.3 m within sediments and the sediments used here were, being fluvial, relatively heterogeneous.

A further complication arises from the inability of ICP-MS to differentiate between the different uranium decay series ^{238}U and ^{235}U. An assumption is often made during OSL dating that the decay products of these isotopes are in equilibrium; however environmental conditions, particularly the movement of water through a sediment, can preferentially remove ^{238}U from the ^{238}U – ^{210}Pb-decay chain causing the dose rate received by that sediment to vary over time (Olley *et al* 1996). A more homogeneous sample (e.g. dune sand or loess) would not present the same issue, nor would a chemically-closed depositional environment after burial (Olley *et al* 1996). The effect on dose rate disequilibrium will typically be <3%, however past changes to precipitation and ground water movement can influence that effect (Olley *et al* 1996). To account for an element of variation of water content over time the value for each sample was treated as ±5%. It would therefore be reasonable to regard age calculations based on ICP-MS data in this instance as indicative, and likely to be a minimum age (Sven Lukas, pers. comm.).

Table 7.4. Summary of OSL age calculations produced using K, U and Th concentrations determined by inductively-coupled-plasma mass spectrometry (ICP-MS). Water content (Water C.) error margin ranges used in calculations: [1] 7 to zero; [2] 9.5 to zero; [3] 8.3 to zero.

Sample ID	n	K (%)	U (ppm)	Th (ppm)	Water C. (%)	D (Gy ka^{-1})	D_e (Gy)	Age (ka)	MIS
BRW08-02Qz	16	0.38 ±0.03	0.21 ± 0.01	1.18 ± 0.02	2±5 [1]	0.64 ± 0.06	127.94 ±8.68	200.4 ±22.8	6-7
HAP10-02Qz	14	1.27 ±0.03	0.76 ± 0.01	5.08 ± 0.02	6.4±5	1.75 ± 0.11	208.36 ±13.51	119.1 ±10.7	5d - 5e
HAP10-03Qz	23	0.28 ±0.01	0.25 ±0.002	1.62 ± 0.01	4.5±5 [2]	0.56 ± 0.04	127.26 ±9.79	229.0 ±23.7	7-8
HOR211-06Fs	13	0.56 ±0.01	0.49 ±0.001	1.02 ± 0.01	5.9±5	1.61 ± 0.08	160.15 ±11.3	99.2 ±8.7	5b-d
WAC10-03Fs	12	0.67 ±0.01	0.52 ± 0.01	4.24 ±0.03	3.3±5 [3]	2.05 ± 0.12	114.1 ± 8.93	55.6 ±5.4	3-4

Two key internal tests of the luminescence properties of a sediment, recycling and recuperation, can indicate the accuracy of the SAR protocol and therefore the ages produced. The former relates to the correction for sensitivity change within the SAR sequence, by comparing the signal produced by the same regenerative dose (1000 Gy in this study) applied at the beginning and again at the end of the SAR (the recycling ratio). The latter measures the amount of signal induced by the preheat stage of the SAR sequence after the application of a zero Gy regenerative dose. This recuperated signal, if present, has been thermally stimulated to transfer from light-insensitive to light-sensitive traps, therefore producing a measurable signal despite the fact that the regenerative dose was zero. Table 7.5 shows the performance of the quartz samples HAP10-02, HAP10-03 and BRW08-02 are generally good, with mean recycling ratios of 1.02, 1.01 and 0.99 respectively showing reliable performance of the SAR. Recuperation, expressed as mean thermal transfer, is present but minimal (1.09 to 1.98%), well within the 5% maximum value of the natural signal put forward by Murray and Wintle (2000). The feldspar samples WAC10-03 and HOR211-06F similarly indicate reasonable recycling but with more thermal transfer present. Recycling ratios of 0.97 for both samples are well within the suggested limit of ±10% (Murray and Wintle 2000), however recuperation in sample HOR211-06Fs is approaching their 5% limit (ibid). The general good performance of the luminescence properties of the samples indicates that the test procedures applied successfully isolated the well-behaved parts of the samples.

Table 7.5. Summary of the luminescence characteristics of samples.

Field Code	Sequence number	Mean recycling ratio	Mean thermal transfer (%)	Rejected aliquots (%)
HAP10-02Qz	0006	1.01	1.09	34/48 (70.83)
HAP10-03Qz	0008	0.99	1.98	25/48 (52.08)
BRW08-02Qz	0010	1.02	1.42	32/48 (66.67)
WAC10-03Fs	0028	0.97	4.08	12/24 (50.00)
HOR211-06Fs	0034	0.97	3.60	11/24 (45.83)

7.6 Interpretation

The initial dataset of age calculations produced (Table 7.4) indicate potential issues to be addressed in terms of how ages relate stratigraphically. Samples HAP10-02Qz and HAP10-03Qz (Test Terrace 3) derive from sequential sand lenses within the same fluvial terrace yet differ by around 110 ka. Sample BRW08-02Qz is taken from the next (lower) terrace identified in the River Test sequence (Terrace 2) and as such the age is stratigraphically consistent, i.e. younger than HAP10-03Qz, but not within ± uncertainty. BRW08-02Qz is comparable to the youngest date already reported for Terrace 2 in the Test region of 203.6±17.7 ka (MIS 6-7c) (Bates *et al*. 2004), although the age calculation for HAP10-03Qz also falls within the PASHCC study's range of MIS 6-8 for Terrace 2 (with a weighted mean of 217±22 ka (MIS 7)). The results produced here suggest aggradation of Terrace 3 during MIS 7-8 followed by Terrace 2 during MIS 6-7. That sequence would also be stratigraphically consistent with the dating of the Lepe last interglacial sediments (MIS 5e; ~118-130 ka) in that Terraces 2 and 3 are interpreted as being higher and therefore older than the Milford on Sea terrace that contains the Lepe sequence (see Chapter 8). The feldspar samples HOR211-06Fs and WAC10-03Fs appear young. The latter is thought to derive from the same fluvial terrace as HAP10-02 and 03Qz based on their close proximity in location (in neighbouring gravel pits at Warsash) and similar altitude, yet the sample produced a date of 55.6±5.4 ka (MIS 3-4). Sample HOR211-06Fs (99.2 ±8.7; MIS 5a-d) derives from the Stanswood Bay terrace of the Western Solent that has previously produced an age calculation of 245±15 ka (MIS 7b-8) (weighted mean) (Briant *et al*. 2006).

A complicating factor would appear to be issues of the homogeneity of samples not detected by ICP-MS analysis as discussed above. The dose rates calculated for the majority of samples in this study appear to be high, possibly indicative of the presence of a greater concentration of highly radioactive emitters such as zircons. The dose rates for HAP10-02QZ, HOR211-06Qz and WAC10-03Fs are around 3 to 4 times those of BRW08-02Qz and HAP10-03Qz (Table 7.4). They also fall outside the range of dose rates from PASCHH studies, which reported rates of 0.29-0.68 (Gy ka^{-1}) in the Western Solent (Briant *et al*. 2006) and 0.81-1.19 (Gy ka^{-1}) for the majority (10) of Test samples. The latter region did produce two samples with higher rates of 1.61

and 2.31 (Gy ka^{-1}), comparable to those for samples HAP10-02QZ, HOR211-06Qz and WAC10-03Fs, but these were based on Neutron Activation Analysis (NAA) rather than *in situ* gamma spectrometry.

Figure 7.9 shows details of the sedimentary logs recorded at the sample locations HAP10-02Qz, HAP10-03Qz, BRW08-02Qz, WAC10-03Fs and HOR211-06Fs. The sand bed that yielded sample WAC10-03Fs was notably thin at just 17 cm, potentially introducing contributions from unaccounted external gamma sources from the gravels above and below (Table 7.6). The bed that yielded BRW08-02Qz, at 25 cm, was also somewhat thinner than the 60 cm gamma field that an *in situ* gamma spectrometer will measure. The sand beds sampled for HAP10-02 QZ and 03 QZ were nearly thick enough to encompass the entire gamma field, and were targeted to minimise the inclusion any visible clasts in the upper and lower bed respectively.

Table 7.6. Summary of sedimentary information at OSL sample locations.

	Sample				
	HAP10-02Qz	HAP10-03Qz	BRW08-02Qz	WAC10-03Fs	HOR211-06Fs
Sample depth below ground surface	2.21 m	2.36 m	1.60 m	3.01 m	2.48 m
Sample bed sediment	Medium sand, some fe staining, slightly gravelly in right of bed; some horizontal bedding	Fine sand, with slightly clayey grey band and patches; some fe staining; sub-parallel bedding aligned with lower boundary	Sand. Medium grained; planar cross-stratified; yellow; pebbly in places (to left of section)	Sand, medium to coarse; some horizontal bedding; some fe staining	Sand. Fine to medium; faint horizontal bedding
Unit thickness	0.55 m	0.36 m	0.25 m	0.17 m	0.68 m
Superjacent sediments	Sandy fine to coarse gravel with occasional cobbles; medium matrix; some crude horizontal bedding	Medium sand, some Fe staining, slightly gravelly in right of bed; some horizontal bedding	Sand. Fine grained ripples in places	Sandy, very fine to coarse gravel; medium to coarse matrix; some crude horizontal bedding	Gravel. Fine to coarse clasts; crude horizontal bedding; clast-supported in places
Subjacent sediments	Fine sand, with slightly clayey grey band and patches; some fe staining; sub-parallel bedding aligned with lower boundary	Sandy fine to coarse gravel with occasional cobbles; compact; ; horizontally bedded; fe pan layer 5 to 10 cm from top of strata; fe stained	Gravel. Crude sub-horizontal bedding; flint, medium to coarse	Sandy, very fine to medium gravel; coarsening downward; horizontally bedded	Gravel. Fine to coarse clasts; massive
Sample depth to bedrock	2.59 m	2.44 m	1.72 m	1.99 m	1.86 m
Bedrock	Clay, slightly silty	Clay, slightly silty	Sand	Clay, slightly silty	Sand

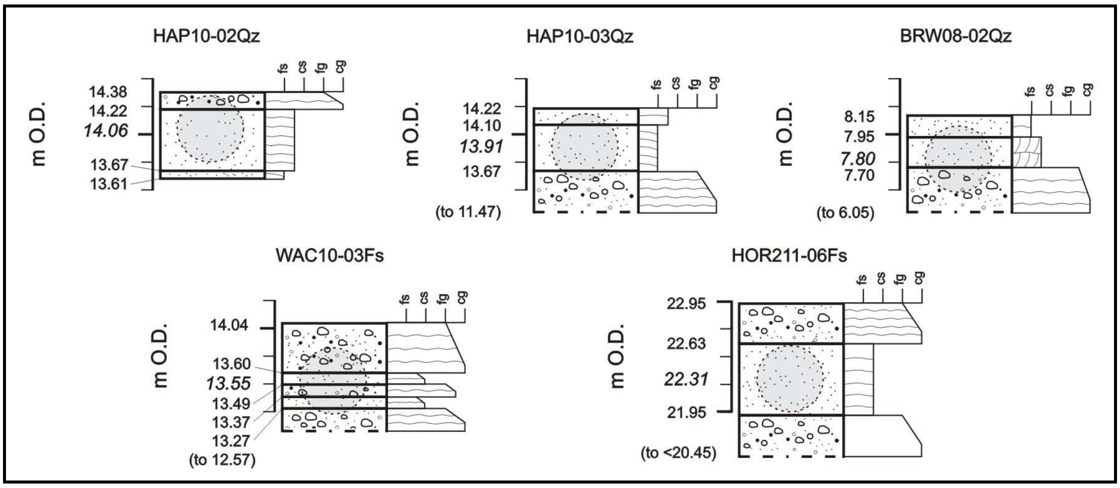


Figure 7.9. Sedimentary logs of OSL sample locations HAP10-02Qz, HAP10-03Qz, BRW08-02Qz, WAC10-03Fs and HOR211-06Fs. Sample location altitude (m O.D.) in italics. The 60 cm field around each sample location which may contribute to the dose rate is indicated.

The expected antiquity of the sediments dated meant that partial bleaching was not considered to represent a significant issue; if a signal of a few thousand years did remain in incompletely bleached samples, the affect on the ages produced (>130 ka) would not be great (Frank Preusser, pers. comm.).

The different behaviours evident in the dose rates calculated for samples may be linked to different bedrock lithologies upstream and at site locations in the region and their heavy mineral components (Table 7.7) described below. The heavy mineral Associations X, Y and Z assessed for the region (Morton 1982) each contain moderately or commonly occurring zircon as a major component. The samples collected at Warsash (HAP10-02Qz/ -03Qz and WAC10-03Fs) are located overlying the Marsh Farm Formation. Edwards and Freshney (1987) describe two main lithologies in the Marsh Farm Formation: i) variably carbonaceous laminated clays with laminae/thin beds of very fine-grained to fine-grained sand and silt; and ii) fine-grained to coarse-grained, quartz dominated, sparsely glauconitic sand with clay beds and laminae of varying frequency, with some carbonaceous debris commonly present and occasional mica. They also note that lateral and vertical variations in the proportions of sand and clay present in the Marsh Farm Formation can be rapid, within an order of a few tens of metres. At Warsash Common and Hamble Park the bedrock was clay, though only the top ~0.75 m of bedrock was exposed in either section. Clay-mineral analyses from their Ramnor Inclosure borehole (Edwards and Freshney 1987) show the formation consists of an illite>smectite>kaolinite proportioned assemblage (up to 30% smectite) in the upper part of the formation and an illite>kaolinite>smectite assemblage (up to 35% kaolinite) in the lower part (Edwards and Freshney 1987). The samples collected at Brownwich Lane, BRW08-02Qz are located overlying the Selsey Sand Formation. Edwards and Freshney (1987) describe the Selsey Sand as consisting of glauconitic, bioturbated, commonly shelly, sandy silt to silty fine-grained sand with a variable clay content; the sands being quartz dominant with variable amounts of glauconite, silt and clay.

The majority of the Western Solent region, including the Hordle Cliff location of sample HOR211-06Fs, is mapped as Headon Beds and Osborne Beds (Undifferentiated) as the area lacks a BGS Memoir. In the Southampton Memoir, Edwards and Freshney (1987) describe the Headon Beds in three parts: i) the lower part dominated by relatively sand-free, shelly clay with medium-grained silt and very fine-grained sand, ii) a middle part of extremely silty or sandy clay with clayey very fine-grained sand or silt, and iii) an upper part lithologically similar to the lower Headon Formation. Clay-mineral analyses from the Ramnor Inclosure borehole show an upward increase in kaolinite content (ranging from 20% up to 30%) and an overall assemblage of illite>smectite≅kaolinite until high in the upper formation when it becomes illite>kaolinite>smectite (Edwards and Freshney 1987).

Three heavy mineral associations are identified in the Hampshire Basin Palaeogene strata by Morton (1982) (Table 7.7), indicative of changes in source area. The associations are defined in terms of a number of characteristics: i) the content of minerals that show the greatest variation over the basin (the major components in Table 7.7), ii) minor mineral content, iii) the types of tourmaline present and iv) the staurolite/kyanite ratio (Morton 1982). The tourmaline types assessed in Table 7.7 are those most indicative of the nature of source rocks (Morton 1982), in that type E tourmalines can show an igneous or hydrothermal source (e.g. Brammall and Harwood 1925) while a signal dominated by type F tourmalines can show a regional metamorphic terrain (e.g. Potter and Pryor 1961). When these data are taken in combination the sands of Association X are assessed to derive from a Scottish origin, sands of Association Y are of Armorican massif origin while sands of Association Z derive from the Cornubian massif (Morton 1982).

The attribution of the Morton (1982) heavy mineral associations can be seen in Table 7.8. In the Marsh Farm Formation the sequence consists largely of Associations Y and Z, with an increasing proportion of Association X in the upper part. The sands of the Headon Formation contain heavy minerals dominated by Association X with some contribution from Associations Y and Z in all parts, less so in the middle part. The Selsey sand sequence sees a transition from Association Z to Y to X in the upper, middle and lower parts respectively.

Table 7.7. Characteristics of heavy mineral Associations X, Y and Z (Morton 1982, Table 2).

	Major components						
Association	Epidote group	Garnet	Zircon	Tourmaline	Characteristic minor minerals	Tourmaline types	Metamorphic minerals
X	Common	Common	Moderate	Moderate	Chloritoid Glaucophane Homblende Sphene Tremolite	Low total E+F E/F <1	Andalusite rare: Staurolite ≤ Kyanite
Y	Rare	Moderate	Common	Moderate	Allanite	Moderate total E+F E/F close to 1	Andalusite minor: Staurolite > Kyanite
Z	Rare	Rare	Moderate	Common	Cassiterite Dumortierite Monazite Topaz	High total E+F E/F >>1	Andalusite frequent: Staurolite >> Kyanite

Table 7.8. Heavy mineral Associations X, Y and Z found in bedrock at OSL sample sites and upstream.

Bedrock	Upper	Middle	Lower
Marsh Farm Formation	Association Y & Z with increasing X	Association Y & Z	Association Y & Z
Selsey Sand	Association Z	Association Y	Association X
Headon Beds	Association X dominated with some Y & Z	Association X dominated with decreasing Y & Z	Association X dominated with some Y & Z

7.7 Implications

The PASHCC project carried out OSL dating at six lower terraces in the Western Solent sequence (Bates *et al*. 2004; Briant *et al*. 2006, 2009b and 2009c; Schwenninger *et al.* 2007); Old Milton (Barton Cliff), Tom's Down (Badminston Farm Quarry), Taddiford Farm (Exbury), Stanswood Bay (Stanswood Bay), Lepe (Stone Point) and Pennington (Pennington Quarry) (see Table 2.4). The project also dated five terraces in the Test sequence, Terraces 1 (Timsbury), 2 (Solent Breezes), 5 (Hook), 6 (Ridge) and 8 (Yewtree Cottage), and a brickearth deposit overlying Terrace 3 (Chilling Copse) (Bates *et al*. 2004, 2010; Briant *et al*. 2012). In the Western Solent most confidence is given to those dates produced for the Stanswood Bay terrace (MIS 8-7b) and Pennington Upper Gravel (MIS 5d-3) (Bates and Briant 2009), though the latter did produce ages of some range (34±9 ka and 67±22 ka). The Lepe Lower Gravel also showed a degree of scatter in the four samples (MIS 7-5e) but does suggest a pre-MIS 5e age. The four Old Milton samples produced considerable scatter, suggestive only of MIS 11-8. A minimum age of MIS 8 was suggested for the Tom's Down terrace, with three of the five samples dated yielding similar ages (329±33 ka weighted mean) within a range of MIS 11-8. The Taddiford Farm date is from a single sample (MIS 8-7e). Similarly, the lowest terraces dated in the Test sequence produced the most reliable dates; Terrace 1 (MIS 4) and 2 (MIS 8-6). The remaining dates were problematic; the brickearth overlying Terrace 3 (MIS 3) was a later slope deposit, Terrace 8 only yielded a minimum age (>MIS 7), and Terraces 5 (MIS 9-8 and 8-7a) and 6 (MIS 8 and 12-11) produced varying ages from two replicated samples each.

The methods applied, while rigorous in their analysis of the ages produced by samples, were less comprehensive in attempting to detect potential issues that are not identified during the standard SAR protocol to calculate ages (see Chapter 3.3.5). The same preheat temperatures of 260° C (Preheat 1) and 220° C (Preheat 2) (see Chapter 3.3.4) were used for each sample, with no prior assessment (i.e. a PHT) of which thermal pre-treatment would remove the unstable signal component in the signal. Recycling ratios were all between ±10% and thermal transfer was low, but dose recovery tests (DRT) were not conducted. A DRT would indicate which preheat temperatures in the test SAR applied resulted in accurate recovery of a given dose. Finally, D_e was calculated as the weighted mean of between 5 and 12 aliquots per sample. Results from testing the suitability of samples (within the same river system) during this study (see Tables 7.3 and 7.4) indicate a failure rate of at least 46% of aliquots. The three best behaving samples, HAP10-03Qz, WAC10-03Fs and HOR211-06Fs, had failure rates between 46-52%, and BRW08-02Qz, HAP10-02Qz, and HOR111-04Fs failure rates were 67%, 71% and 87% respectively. If the PASHCC samples exhibited similar luminescence characteristics the majority of aliquots used may have been questionable, leaving a small sample size of limited statistical robustness. The use of standardised SAR protocols and a test programme more limited than the ideal, combined with the reported scatter of ages produced by replicated samples within terraces, calls into question the reliability of those ages.

The complicated nature of the fluvial sediments of the Solent River system has been highlighted by the comprehensive test programme carried out in this study. Ages produced for Terrace 2 and 3 of the River Test, samples BRW08-02Qz and HAP10-03Qz respectively, are used in a revised MIS model constructed using the most reliable chronological tie-points currently available (Table 8.2). The proposed stratigraphic sequence and correlations between the different elements of the Solent River, the River Test and the River Stour are then assessed in light of the suggested chronology of that framework (Chapter 8.1, 8.3).

CHAPTER EIGHT: DISCUSSION

This study aimed to expand and enhance the available data relating to the Pleistocene fluvial deposits of the Solent River and the tributary rivers Stour and Test in order to evaluate and, if necessary, revise existing stratigraphic schemes. In doing so the archaeological record of the Solent region would be better contextualised and therefore more able to contribute to questions regarding the hominin occupation history of southern Britain during the Middle-Late Pleistocene. Previous studies in the region have been focused on the Pleistocene evolution of the Solent River System (Allen 1991; Allen and Gibbard 1993; cf. Westaway *et al.* 2006), investigating the Palaeolithic record of the River Test, and correlating the eastern Solent (i.e. Test Valley) with the Sussex Raised beaches (the PASHCC project) (Bates *et al*. 2004, 2007; Bates and Briant 2009). Other studies (Bates 2001; Briant *et al.* 2006, 2009b & c, 2012; Schwenninger *et al.* 2007; Briant and Schwenninger 2009; Bates *et al.* 2010; Briant *et al*. 2013), largely borne of the PASHCC project, have added important data at key locales in the region and offered some stratigraphic interpretation of and between elements of the Solent River system and the Sussex Raised Beaches. This study however is the first comprehensive attempt to correlate the archaeologically important Bournemouth, Western Solent and River Test terrace stratigraphies. Previous work has been based on fragmentary and spatially dispersed data in trying to correlate often fragmentary and spatially dispersed terrace remnants. This is the first extensive examination of a large data set, intended to produce a more robust terrace stratigraphy and correlations both sub-regionally and between the main elements of the Solent system.

Chapters 4, 5 and 6 presented revised stratigraphic schemes for the fluvial deposits of the Test Valley, Western Solent and Bournemouth regions respectively, based on new data collected during this study, an analysis of the extensive borehole archive and interpretation of previous studies in the region. Chapter 7 presented the results of a rigorously-tested OSL dating programme conducted at key sites in the Solent region, aimed at improving the chronology of the Solent River system’s development. This chapter draws the various data together to correlate the fluvial sequences of elements of the Solent River system and goes on to discuss the implications of the results produced in this thesis for the Palaeolithic archaeology of the region.

8.1 The Pleistocene evolution of the Solent River and its major tributaries

Building on the stratigraphies developed in Chapters 4, 5 and 6, terrace long profile gradients were calculated (as described in Chapter 3.6.3) in order to correlate between the three key regions of the Solent system, those of the River Test Valley, the Western Solent region and the Solent deposits around Bournemouth, and to further correlate the latter with the Stour deposits around Bournemouth. The terrace gradients calculated for the main Western Solent sequence of terraces, comprising the majority of the surviving Palaeo-Solent remnants and situated between the Bournemouth and Test regions, were projected upstream and downstream to compare their elevation to those of the terraces of the Bournemouth Solent and the River Test (see Figure 8.2 below). The terrace gradients produced by this study are described in the following section and summarised in Tables 8.1 and 8.2 and Figures 8.2 and 8.3 below. In general the gradients produced for the Western Solent terraces in this study are more comparable to the steeper gradients proposed by Allen and Gibbard (1993) than those of Westaway *et al*. (2006). They are also comparable to those gradients calculated by this study for terraces in the lower reach of the Test Valley, south/southeast of the tributary Hamble River, where the Solent-Test confluence would have been located during each successive stage (as discussed below).

As discussed in Chapter 5.7 the Stanswood Bay terrace is largely agreed upon in terms of its upstream/downstream extent in the Western Solent. This was the basis of its use as a key terrace in the reassessment of the Western Solent sequence. Despite this agreement there is a substantial difference in gradients produced by the various studies (Table 8.1) which requires scrutiny. The upstream borehole used by Westaway *et al*. (2006) to calculate the gradient of the Hordle/Stanswood Bay terrace (MAR borehole SZ29 SE4 (at SZ 2724 9213)) records ground level at 19.9 m O.D. and bedrock at 13.4 m O.D. Westaway *et al*. (2006) use the top of the gravel at 19.0 m O.D. in their long profile gradient projection but do not state what location or elevation is used downstream. Borehole SZ29 SE4 is located near the front edge of their Hordle/ Stanswood Bay terrace and is the furthest upstream borehole log. The coastal exposure at Hordle Cliff, 850 m upstream in the same mapped terrace unit (Westaway *et al*. 2006), was surveyed during this study over ~100 m (Chapter 5.4). The resulting synthetic borehole logs HOR SBH1 (ground level 23.62 m O.D., gravel surface 23.36 m O.D., bedrock 19.11 m O.D.) and HOR SBH2 (ground level 24.66 m O.D., gravel surface 23.13 m O.D., bedrock 20.13 m O.D.), record the Stanswood Bay/Hordle terrace stratigraphy notably higher than in borehole SZ29 SE4. How representative SZ29 SE4 is of the Stanswood Bay/Hordle terrace is therefore questionable, as is its use in gradient calculation.

In the construction of their Stanswood Bay terrace gradient (Figure 8.1) Allen and Gibbard (1993) use the same MAR borehole (SZ29 SE4) upstream and their Stanswood Bay stratotype downstream (ground level 9.0 m O.D., gravel surface 8.5 m O.D., bedrock 3.1 m O.D.). Allen (1991) notes that of the three locations examined in the upstream half of the Stanswood Bay terrace profile the MAR borehole is at the lowest elevation but this is attributed to the possibility that the next two records may belong to a higher terrace level. However, using data from borehole SZ29 SE4 in the Stanswood Bay profile means that bedrock remains at ~13.4 m O.D. for more than 11 km downstream, around half the length of the terrace distribution (Figure 8.1). The correspondingly flat gradient that results does not appear on that basis to be a realistic projection of the Stanswood Bay terrace. Analysis discussed in Chapter 5.7 found HOR SBH1 and SBH2 to be more representative of the Stanswood Bay terrace (Figure 8.1).

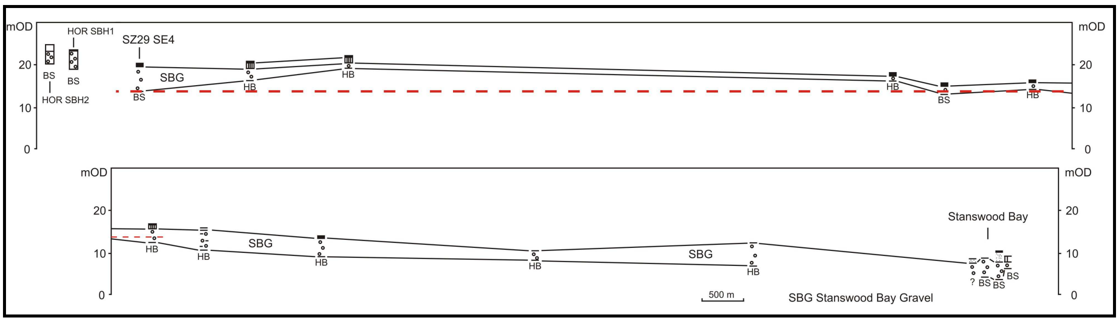


Figure 8.1. The Stanswood Bay long profile of Allen (1991; Allen and Gibbard 1993) showing no overall gradient change for around half its distribution. The red dashed line shows bedrock level from borehole SZ29 SE4 (13.4 m O.D.) matches that recorded ~11 km downstream. HOR SBH1 and SBH2 recorded at Hordle Cliff for this study are included for comparison. Bedrock key: BS Barton Sand; HB Headon Beds. Redrawn from Allen (1991).

It could be argued that the discrepancy in gradient calculations again illustrates the problems that can arise from constructing long profile gradients, and by extension long profile correlations, based on limited datasets. In this case both Allen and Gibbard (1993) and Westaway *et al*. (2006) use a single borehole record at one end of a terrace sequence, which may or may not be representative of that terrace level. In reassessing the Stanswood Bay terrace during this study (Chapter 5.7) borehole SZ29 SE4 was reattributed to the stratigraphically lower Milford on Sea terrace. Further minor adjustments were made to the spatial extent of the Stanswood Bay terrace, but the agreed upon exposures of the terrace at Hordle Cliff and Stanswood Bay remain (see Figures 2.15 and 2.16).

Table 8.1. Comparison of terrace long profile gradients calculated by Allen & Gibbard (1993), Westaway *et al.* (2006) and those produced in this study.

Allen & Gibbard (1993) model		Westaway *et al.* (2006) model		Revised stratigraphy	
Terrace	Gradient	Terrace	Gradient	Terrace	Gradient
Holmsey Ridge	0.54 m km^{-1}	Holmsey Ridge	Not specified	Holmsey Ridge	0.60 m km^{-1}
		Wootton	Not specified		
Sway	0.50 m km^{-1}	Sway	Not specified	Sway	0.61 m km^{-1}
Tiptoe	0.51 m km^{-1}	Tiptoe	Not specified		
Beaulieu Heath	Not calculated	Beaulieu Heath	0.25 m km^{-1}	Beaulieu Heath	0.88 m km^{-1}
Setley Plain	0.66 m km^{-1}	Setley Plain	0.4 m km^{-1}	Setley Plain	0.71 m km^{-1}
Mount Pleasant	0.64 m km^{-1}	Mount Pleasant	Not specified	Mount Pleasant	0.61 m km^{-1}
Old Milton	0.49 m km^{-1}	Old Milton	Not specified	Old Milton	0.50 m km^{-1}
		Ensbury Park/ Becton Farm	Not specified		
Tom’s Down	0.67 m km^{-1}	Downton/ Tom’s Down	0.4 m km^{-1}	Tom’s Down	0.73 m km^{-1}
Taddiford Farm	0.63 m km^{-1}				
Stanswood Bay	0.44 m km^{-1}	Hordle/ Stanswood Bay	0.4 m km^{-1}	Stanswood Bay	0.75 m km^{-1}
Milford on Sea	0.42 m km^{-1}	Milford on Sea	Not specified	Milford on Sea	0.64 m km^{-1}
Lepe	0.35 m km^{-1}	Rook Cliff/ St Leonard’s Farm	0.4 m km^{-1}		
Pennington	Not calculated			Pennington	1.2 m km^{-1}

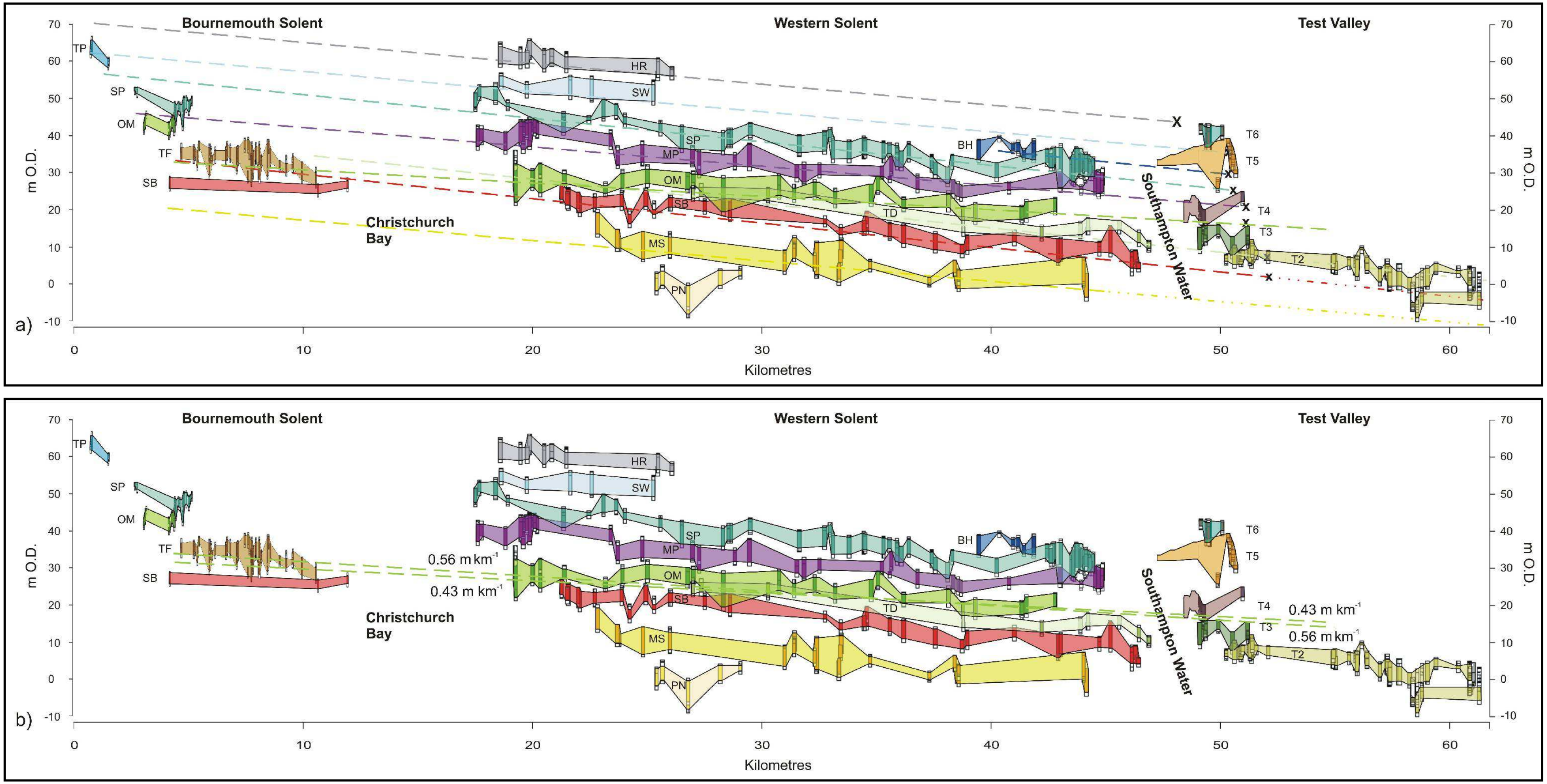


Figure 8.2. Long profile projections of the terraces of the Solent River in the Bournemouth region, the main Western sequence and the terraces of the River Test downstream of the River Hamble. a) With Western Solent terrace gradients extended upstream and downstream. Gradient values as Table 8.1. Intersections of the projected Western Solent terrace gradients with the east bank of the River Test are indicated with an **X**. b) Comparing the range of Old Milton gradients as described in the text. Terrace nomenclature: HR Holmsey Ridge; SW Sway; TP Tiptoe; BH Beaulieu Heath; SP Setley Plain; MP Mount Pleasant; OM Old Milton; TF Taddiford Farm; TD Tom's Down; SB Stanswood Bay; MS Milford on Sea; PN Pennington; Test terraces labelled T1 to T6.

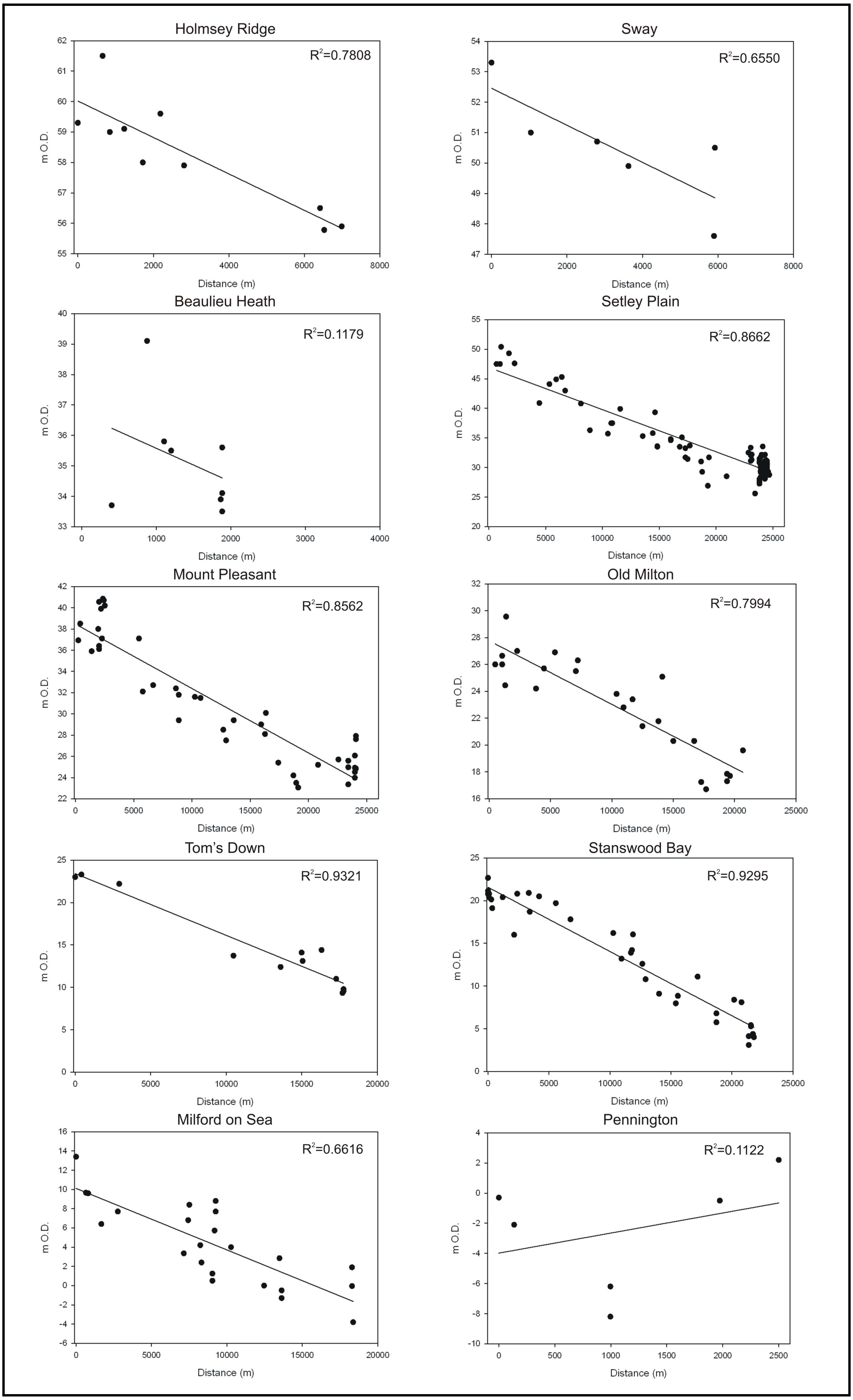


Figure 8.3. Data used in the production of terrace long profile gradients in the Western Solent region. Linear regression equation: f = y0+a*x.

Table 8.2. Associated statistics for the linear regression (f = y0+a*x) data shown in Figure 8.3 above.

Terrace	R^2	Variable	Coefficient	Std. Error	t	P
Holmsey Ridge	0.7808	y0	60.0166	0.4356	137.7670	<0.0001
		a	-0.0006	0.0001	-5.3377	0.0007
Sway	0.6550	y0	52.4552	0.8638	60.7231	<0.0001
		a	-0.0006	0.0002	-2.7560	0.0511
Beaulieu Heath	0.1179	y0	36.6761	1.8280	20.0639	<0.0001
		a	-0.0011	0.0012	-0.8956	0.4050
Setley Plain	0.8662	y0	46.9040	0.5930	79.0987	<0.0001
		a	-0.0007	0.0000	-25.3118	<0.0001
Mount Pleasant	0.8562	y0	38.4610	0.6042	63.6600	<0.0001
		a	-0.0006	0.0000	-15.4316	<0.0001
Old Milton	0.7994	y0	27.7596	0.6068	45.7465	<0.0001
		a	-0.0005	0.0000	-9.5732	<0.0001
Tom's Down	0.9321	y0	23.4202	0.8545	27.4079	<0.0001
		a	-0.0007	0.0001	-11.7163	<0.0001
Stanswood Bay	0.9295	y0	21.5615	0.4735	45.5400	<0.0001
		a	-0.0008	0.0000	-21.1718	<0.0001
Milford on Sea	0.6616	y0	10.1092	1.0514	9.6145	<0.0001
		a	-0.0006	0.0001	-6.4074	<0.0001
Pennington	0.1119	y0	-3.9811	2.6672	-1.4926	0.2098
		a	0.0013	0.0019	0.7100	0.5169

Sections 2.3.2 and 2.3.3 discussed issues inherent in defining and correlating terrace fragments in downstream projections where lithologic and biostratigraphic information is lacking and/or data points are limited. These problems should be mitigated, where possible, by increased datasets of more closely-spaced distribution such as those produced by this study. Geochronology can also aid stratigraphic differentiation and correlation where available. An assessment of the methodological and conceptual approaches to the construction of long profile projections is made in 8.2 below.

8.1.1 Terrace gradients of the Western Solent and correlation with the River Test

Figure 8.2 shows the Western Solent gradients which are described here from the base of the sequence upwards. The correlations proposed in this study between the Western Solent and the River Test (Figure 8.4) are based on the downstream projected elevations of Western Solent terraces to the approximate Solent/Test confluence locations. The orientation of the Western Solent terraces indicates that the confluence locations were all downstream of the Hamble River.

The available data set for the Pennington terrace is of restricted spatial distribution, limiting the confidence that can be placed in the projected gradient. As currently represented the downstream gradient is 1.2 m km^{-1}, most notable in that it projects northeast to southwest, i.e. in contrast to the general northwest/southeast gradient of the Solent River (Figures 8.2, 8.3 and 8.4). This anomaly may however simply be a function of the limited dataset. The terrace level does not correlate with any onshore terrace downstream in the Test Valley. The equivalent terrace level may be seen in the River Stour deposits around Bournemouth (Terrace 8, see below), but as the equivalent terrace level does not survive in the Solent around Bournemouth the correlation of a Stour and Bournemouth Solent Terrace 8 cannot be stated with certainty.

The downstream gradient of the revised Milford on Sea terrace is 0.64 m km^{-1} and projects to the level of the lower gravel deposits seen in boreholes around Gosport as discussed in Chapter 4.7. The sedimentary evidence in the Gosport boreholes would indicate lower and upper gravel units separated by peat with organic silt and/or clay deposits. Clays similar to those at Stone Point (West and Sparks, 1960; Brown *et al*. 1975; Briant *et a*l. 2009) and West Street, Selsey (Bates *et al*. 2009) have been found underlying terrace gravels near Lee-on-Solent (SU 573 003 and SU 5630 0017), just upstream and in the same terrace as Gosport. However the age of the deposits, their depositional environment and their relationship to the overlying gravels is not known (Lake *et al*. 1985). A terrace gradient for the lower gravel deposits cannot be discerned from the limited dataset.

The downstream gradients of the next two terraces, Stanswood Bay and Tom's Down, are 0.75 m km^{-1} and 0.73 m km^{-1} respectively. The Stanswood Bay terrace projects to an elevation correlative to the Test Terrace 2 deposits, the latter showing a continuation of a similar downstream terrace gradient of around 0.7 m km^{-1}. The downstream gradient of the Tom's Down terrace projects to a similar elevation to Terrace 3 of the Test. The Tom's Down terrace is recognised here as an intermediate level between the Stanswood Bay and Old Milton terraces, better developed to the east of the Western Solent region.

The downstream gradient of the Old Milton terrace was originally calculated as 0.43 m km^{-1} before being revised to 0.50 m km^{-1} as described below. The gradient is notably shallower than elsewhere in the sequence, but comparable to the gradient of 0.49 m km^{-1} calculated by Allen and Gibbard (1993). Examining the Old Milton terrace gradient within the rest of the sequence (Table 8.1) highlights that it appears to be anomalously gentle compared to other terrace levels. It is possible that the revised Old Milton terrace is a composite of two poorly separated terraces, with elements of a lower terrace level causing a shallower gradient calculation. This would most likely be the case upstream of the Tom's Down terrace deposits, an area where previous schemes have mapped intermediate terraces between the Old Milton and Stanswood Bay levels (the Taddiford Farm terrace of Allen and Gibbard (1993) and Becton Farm and Downton terraces of Westaway *et al.* (2006)). Such a terrace level was not identified in the mapping evaluation methods used here however, and the revised Old Milton terrace appears (Figure 8.4) to show similar vertical variation in its borehole record as the rest of the sequence. A re-examination of the Old Milton terrace in the Barton on Sea area (as discussed in Chapter 5.7) shows that the terrace gradient flattens upstream as it reaches Christchurch Bay. Borehole records at the back edge of the terrace have a similar bedrock altitude to those at the front edge (as exposed on the coast at Barton) while the terrace shows thickening of gravel deposits front to back. As such it is unlikely that any of these records can be attributed to another terrace level; instead two boreholes in particular seem to indicate localised bedrock surface variation (e.g. due to a channel or scour feature). For this reason the borehole records SZ29 SW26 (at the upstream end of the reach at New Milton) and SZ39 NW4 (at Battramsley) were excluded from the profile calculation, increasing the gradient to 0.50 m km^{-1}. A closer examination of the projection reveals that excluding every potentially problematic upstream log around Barton on Sea (including Allen and Gibbard's (1993) type site and nearby fieldwork carried out for this study) would increase the gradient to 0.56 m km^{-1}, still notably shallower than the rest of the sequence. Imposing a gradient similar to that of the Stanswood Bay or Tom's Down terraces (~0.75 m km^{-1}) would result in the Tom's Down terrace, currently well-defined as a separate downstream terrace level, becoming incorporated into the Old Milton terrace (Figure 8.4). The resulting terrace would have far greater variation in bedrock, gravel surface and ground level elevations than any other in the sequence. It would therefore appear that the mapping and gradient calculation is robust and that the Old Milton terrace is shallower by at least 0.11 m km^{-1} than the rest of the sequence, which may be a response to changes in base-level or reflect a coarse change. If the calculated gradient of the Old Milton terrace (0.50 m km^{-1}) is used the terrace projects downstream to the elevation of Terrace 4 of the Test sequence.

Between the Beaulieu Heath and Old Milton terraces there are two recognised levels in the Western Solent scheme which project between Terraces 4 and 5 of the River Test. The Mount Pleasant terrace has a downstream gradient of 0.61 m km^{-1}, similar to that of 0.64 m km^{-1} produced by Allen and Gibbard (1993). The Mount Pleasant terrace gradient projects to the highest borehole of Terrace 4 but this borehole has been interpreted (Chapter 4.7) as the back edge of the terrace that correlates with the Western Solent Old Milton terrace as discussed above. The Setley Plain terrace has a downstream gradient of 0.71 m km^{-1} (comparable with that of 0.66 m km^{-1} produced by Allen and Gibbard (1993)) similar to those previously seen in the Stanswood Bay and Tom’s Down terraces. The terrace gradient projects to a similar elevation to the lowest borehole in Terrace 5 in this part of the Test sequence, which has been reassigned from Terrace 3 when examining the borehole record (see Chapter 4.7). It may be the case however that the log represents an outcrop of a previously unrecognised terrace level between Terraces 4 and 5 at the downstream end of the Test (?Terrace 4a). Upstream the elevation of Terraces 4 and 5 are closer, and as such an intermediate terrace level would be restricted to the area south of the tributary River Itchen. It would not be methodologically robust however to recognise a new terrace level based on a single borehole record. There would though appear to be greater vertical separation between terraces 4 and 5 of the Test downstream of the River Hamble than elsewhere based on currently available data and any future fieldwork in the area may be able clarify the sequence here.

Higher up the Western Solent sequence it appears that the Beaulieu Heath terrace projects to the main unit of Terrace 5 after accounting for the higher boreholes located on the eroded edge of Terrace 6 (as discussed in Chapter 4.7). The Beaulieu Heath terrace is not spatially extensive, which limits confidence in the 0.88 m km^{-1} gradient calculated for the eight available borehole logs. The projection of the Sway terrace gradient of 0.61 m km^{-1} downstream brings it to an elevation correlative to Terrace 6 of the River Test. The Beaulieu Heath/Terrace 5 and Sway/Terrace 6 correlations, though not based on extensive datasets, are altitudinally consistent.

8.1.2 Correlation with the Bournemouth region

Correlation of the Bournemouth Solent upstream from the Western Solent, based on the more robustly calculated terrace gradients of the latter region, changes the attribution of a number of terraces as described in previous schemes. The Stanswood Bay terrace of the Western Solent projects above the three available borehole logs of the equivalent named Solent River terrace in the Bournemouth region (= Terrace 9), which is the lowest surviving terrace in the area. The Stanswood Bay terrace does project upstream to the next terrace level, that of Terrace 10. This correlation maintains the gradient of ~0.7 m km^{-1} for the Stanswood Bay terrace from the River Test to the Western Solent and into the Bournemouth region (model A, Figure 8.4a). The Old Milton terrace of the Western Solent also projects upstream to the level of Terrace 10 due to the uniquely shallow gradient the Old Milton terrace produced as discussed above (model B, Figure 8.4b). The Taddiford Farm terrace in the Western Solent region was comparatively restricted in extent (see Chapter 5) and analysis led to it being part incorporated into both the Tom’s Down and Stanswood Bay terraces in the revised scheme. As such the equivalent Bournemouth Solent Terrace 10 is correlated with Stanswood Bay here based on projection gradients (as Figure 8.4a). This correlation results in the possibility that the lowest Bournemouth Solent terrace should be correlated to Milford on Sea, based on its identification in the Western Solent region immediately below the Stanswood Bay terrace. Continuation of the Western Solent Milford on Sea gradient upstream (Figure 8.2) projects it below the three available borehole records of the Bournemouth Solent Terrace 9, which is of limited spatial extent (possibly due to coastal erosion), and may indicate that only the back edge of the terrace survives. Correlation of Milford on Sea with Terrace 9 of the Bournemouth Solent is proposed here to maintain the Western Solent sequence with recognition that future work may revise the correlation.

Terrace 11 in the Bournemouth region, previously correlated with Old Milton, does not appear to have a directly correlative terrace level in the revised Western Solent scheme. The Bournemouth terrace is located ~8 m higher than the projected Western Solent Old Milton terrace level and would require an increase in projection gradient in order to be correlative. As already noted however the Western Solent Old Milton terrace does have a gradient gentler than those of the rest of the sequence, which may be misleading. It may be the case that the two levels are correlative but it is problematic to state that definitively here based on the small dataset in the Bournemouth region and the gradient produced in the Western Solent. There is no alternative that is better than the Old Milton terrace however. In light of the proposed correlation of Terrace 10 (= Stanswood Bay terrace) and that of the next highest terrace level (discussed below) the original stratigraphic order of the Bournemouth Solent is provisionally retained here with Terrace 11 remaining correlative with the Old Milton terrace.

Terrace 12 in the Bournemouth Solent sequence, previously correlated with Setley Plain, is of significantly lower elevation (~10 m) than the Setley Plain terrace seen at the end of the Western Solent distribution and so would not appear to be correlative. Bournemouth Terrace 12 does however correlate with an upstream projection of the Western Solent Mount Pleasant terrace and is therefore correlated here with Mount Pleasant. The final two terrace levels seen in the Bournemouth Solent region, Terrace 13a and Terrace 13b, are only represented by five borehole logs and therefore downstream correlation is tentative. Based on an examination of the data and location of those logs they were all included in a revised Terrace 13a (Chapter 6.4). In the revised Western Solent sequence (Chapter 5.7) the terrace level designated as the Tiptoe terrace in previous schemes has been incorporated into the Setley Plain terrace due to similar elevation and difficulty in separating them vertically, and the realisation that the downstream end of the Setley Plain terrace projected to the Tiptoe deposits upstream. Projection of the upstream gradient of the Western Solent Setley Plain terrace level correlates with Terrace 13a in the Bournemouth Solent, which accordingly is seen as equivalent to Setley Plain in this revised scheme.

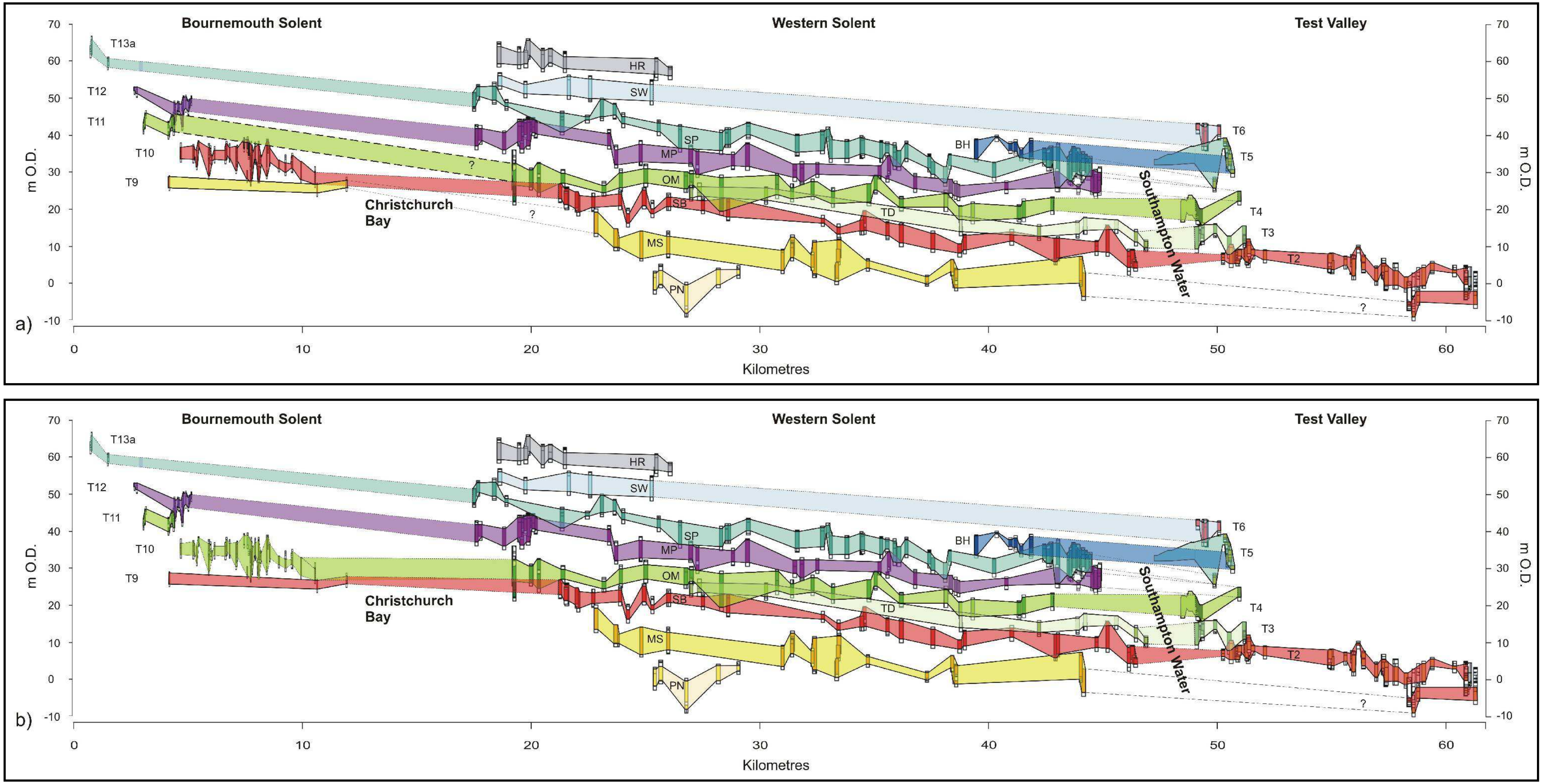


Figure 8.4. Long profile correlations of the terraces of the Solent River in the Bournemouth region, the main Western sequence and the terraces of the River Test downstream of the River Hamble. a) The preferred correlative model A and b) the alternative correlative model B as discussed in the text. Terrace nomenclature: HR Holmsey Ridge; SW Sway; BH Beaulieu Heath; SP Setley Plain; MP Mount Pleasant; OM Old Milton; TD Tom’s Down; SB Stanswood Bay; MS Milford on Sea; PN Pennington; Bournemouth Solent and Test terraces labelled with terrace number and Western Solent correlation.

Correlation of Solent and Stour terrace deposits around Bournemouth (Figure 8.5) seems to show slightly steeper gradients in the latter, as well as confirming that Terrace 13b is not preserved in the Solent River at Bournemouth (at least where borehole records are available) (Chapter 6.4.1). Similar vertical ranges are seen in the terrace stratigraphy of the two areas, with the longer reach of the Stour revealing steeper gradients than those of the Solent. Based on the limited dataset available it would appear that the two sequences are comparable (Table 8.3). The only other difference in the sequences of the Solent and Stour is that Terrace 10 in the former is not seen in the latter. It is not possible to identify a Solent terrace directly correlative to the final terrace level in the Stour, Terrace 13b, due to a lack of available borehole logs. Terrace 13b of the Stour does appear correlative with the Sway terrace downstream in the Western Solent based on comparable elevation. The Terrace 13b = Sway attribution for the Stour is therefore made here with the same caveat as above, that the correlation is based on limited data points.

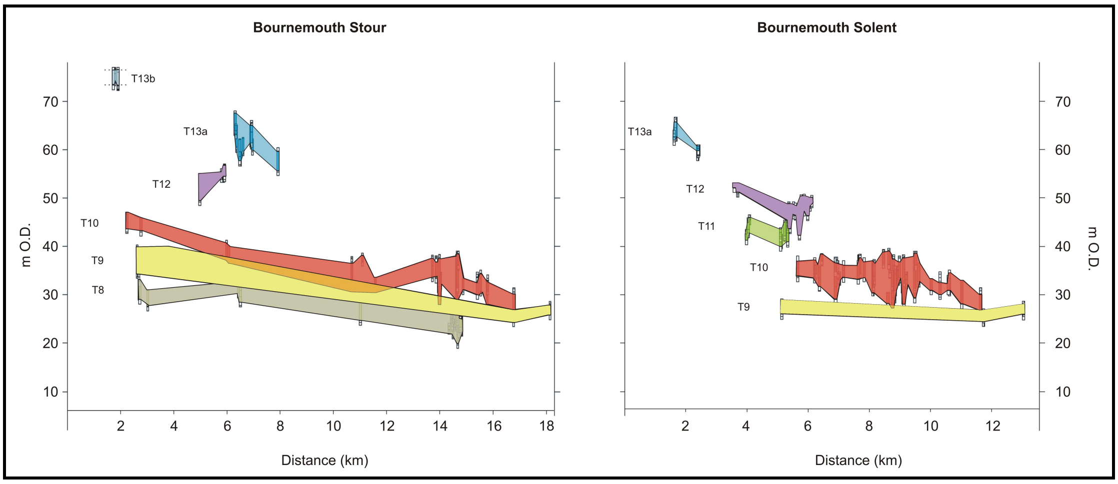


Figure 8.5. Correlation of terraces of the Bournemouth Stour and Solent (based on model A).

Table 8.3 details the revised stratigraphic sequence and proposed correlations between the different elements of the Solent River, the River Test and the River Stour. The chronological model is constructed using data from recent studies and OSL dates produced by this study, with additional information from the nearby Sussex Raised Beaches as discussed below.

Table 8.3. Proposed stratigraphic sequence and correlations between the different elements of the Solent River, the River Test and the River Stour. Bournemouth Solent correlation is model A (see text). Revised chronology of MIS model key: [1] Pennington Quarry, Briant *et al.* 2006; [2] Allen and Gibbard 1993, cf. Allen *et al.* 1996; [3] & [5] Stone Point, Lepe, Briant *et al.* 2006; [4] West and Sparks 1960, Brown *et al.* 1975, Green and Keen 1987; [6] Stanswood Bay, Briant *et al.* 2006; [7] Solent Breezes, Bates *et al.* 2004; [8] Aldingbourne Raised Beach (MIS 7e) and Brighton/Norton Raised Beach (MIS 7a), Bates *et al.* 2010; [9] Brownwich Lane, this study; [10] Dunbridge, Harding *et al.* 2012; [11] Exbury, Schwenninger *et al.* 2007; [12] Hamble Common, this study; [13] Boxgrove, Roberts and Parfitt 1999.

River Stour	Bournemouth Solent	Western Solent	River Test	Sussex raised beaches	Revised MIS model
-	-	Holmsey Ridge	Terrace 7		>13
Terrace 13b	Terrace 13b	Sway	Terrace 6	Goodwood/Slindon Raised Beach	?14/12 (13) [13]
-	-	Beaulieu Heath	Terrace 5		
Terrace 13a	Terrace 13a	Setley Plain	?Terrace 4a		?12-9
Terrace 12	Terrace 12	Mount Pleasant	?		?12-9
Terrace 11	Terrace 11	Old Milton	Terrace 4		?12-9
-	-	Tom's Down	Terrace 3		9-8 [10] 8-7e [11] 8-7 [12]
Terrace 10	Terrace 10	Stanswood Bay	Terrace 2	Aldingbourne Raised Beach; Brighton/Norton Raised Beach	8 (8-7b) [6] 7 (8-6) [7] 7 [8] 6-7 [9]
Terrace 9	Terrace 9	Milford on Sea (lower)	?Terrace 1		6 (7-5e) [5]
		Stone Point, Lepe			5e [4]
		Milford on Sea (Upper)	?Terrace 1		4 (4-3) [3]
(?Terrace 8)		Pennington (lower)	?Terrace 1		6 [2]
		Pennington Marshes			5e [2]
		Pennington (Upper)	?Terrace 1		3 (5d-3) [1]

The chronology of the MIS model in Table 8.3 derives from a number of studies: Biostratigraphical interpretation at Pennington Quarry and Stone Point, Lepe, and OSL dating by the PASHCC project, Harding *et al*. (2012) and for this thesis. Data from the Sussex Coastal Plain (Figure 8.6; Table 8.3) provides additional chronological control on the Test fluvial sequence also based on OSL ages. Bates *et al*. (2010) propose a depositional sequence consisting of the Aldingbourne Raised Beach during MIS 7e, followed by Terrace 2 of the Test (correlative with the Stanswood Bay terrace in the revised scheme presented here) during a cold-stage within MIS 7 and then the Brighton/Norton Raised Beach during MIS 7a. In that scheme the OSL date for Brownwich Lane (Table 8.1; Chapter 7) would place the Terrace 2/Stanswood Bay terrace in 7b or d.

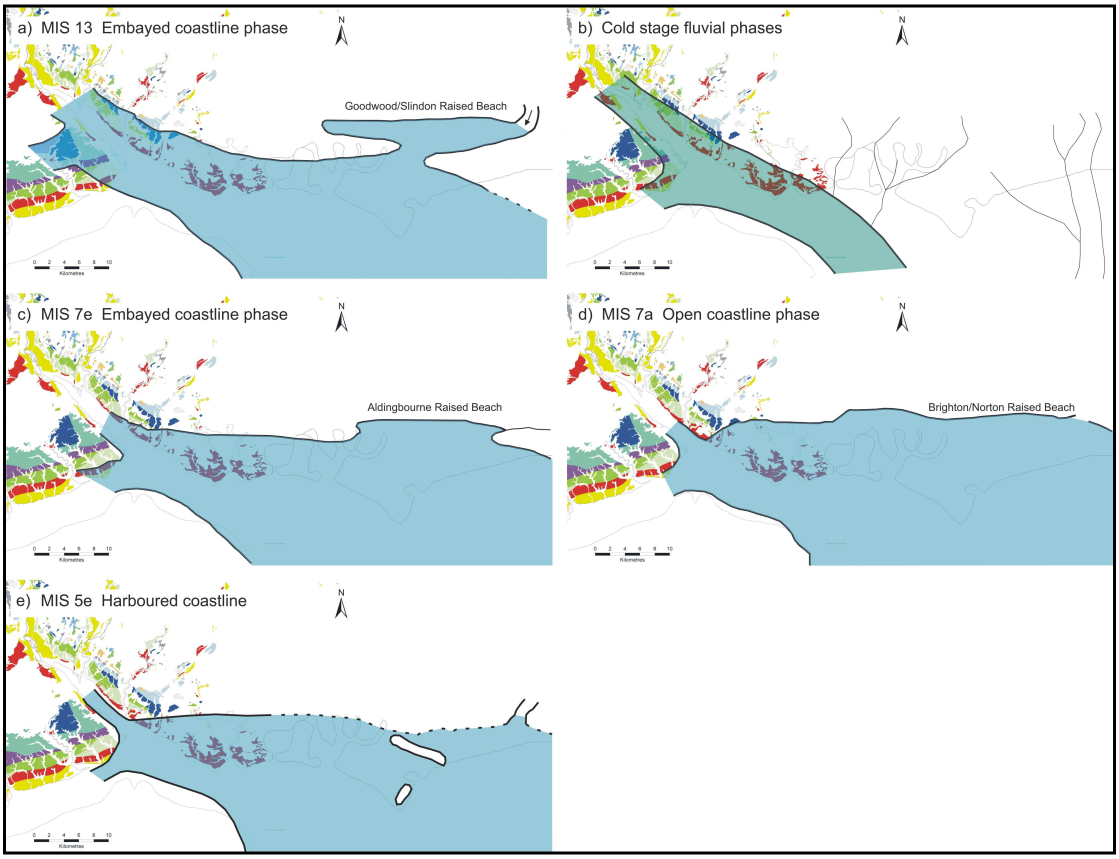


Figure 8.6. The changing palaeogeography of the eastern Solent region and the nearby Sussex raised beaches, adapted from Bates *et al*. (2010) to reflect the revised stratigraphy and proposed chronology in this thesis. a) MIS 13 embayed coastline phase; b) Cold stage fluvial phases; c) MIS 7e embayed coastline phase; d) MIS 7a open coastline phase; e) MIS 5e harboured coastline phase.

The Goodwood/Slindon Raised Beach contains the Boxgrove site attributed to MIS 13 (Roberts and Parfitt 1999) and may provide further chronological control for the Test sequence. Previous work (Bates *et al*. 2004) has proposed a correlation between Terrace 6 of the River Test and a cold-stage before or after the Goodwood/Slindon Raised Beach. The long profile produced in this study indicates such a relationship could be proposed with either Terrace 5 or Terrace 6 based on a westward projection of the level of the Goodwood/Slindon Raised Beach with the lower reaches of the River Test. However, Westaway *et al*. (2006) highlight the possibility that lateral variations in uplift rates associated with the Portsdown anticline would have implications for correlation of fluvial deposits of the Test with marine deposits of the Sussex Raised Beaches. Correlation of the Sussex Raised Beaches with the River Test terraces is further complicated due to the former being warm-stage deposits and the latter likely cold-stage. When the terraces were deposited sea-level would have been some distance away.

The revised stratigraphy produced by this study requires comment on the relationship of the interglacial deposits at Pennington Marshes and Stone Point, Lepe (section 2.4.1). The sites are assigned here to the Pennington and Milford on Sea terraces respectively (Figure 8.4), stratigraphically distinct units with the former beneath the latter. The attribution of MIS 5e ages for each site is stratigraphically inconsistent, implying the possibility of the higher Lepe deposits being MIS 7 as proposed by Allen *et al.* (1996) and Bridgland (2001). Westaway *et al*. (2006) and OSL dates (Bates *et al*. 2004; Briant *et al.* 2006) however support a MIS 5e age for both Pennington and Lepe. The revised stratigraphy produced in this study does not resolve the issue of the timing of deposition of these interglacial sediments, which may still be best explained as occurring early in MIS 5e (Pennington) and during the later high sea-level stand in MIS 5e (Lepe).

Chapter 7.7 critiqued previously published OSL dates for the Solent region. The methods employed did not test samples to the degree conducted in this study (Chapter 3.3.5) and therefore would have not detected issues that arose here (and caused so many aliquots to be rejected). They are also acknowledged to be problematic for all but the lowest terraces sampled (Bates and Briant 2009; Briant *et al*. 2012). In constructing a revised MIS model, data from five lower terraces and two Raised Beaches have been used: Pennington Quarry (Briant *et al.* 2006); Stone Point, Lepe (Briant *et al.* 2006); Stanswood Bay (Briant *et al.* 2006); Solent Breezes (Bates *et al.* 2004); Exbury (Schwenninger *et al.* 2007); Aldingbourne Raised Beach (MIS 7e) and Brighton/Norton Raised Beach (MIS 7a) (Bates *et al.* 2010). If these ages are robust the MIS model in Table 8.3 is the most comprehensive that is currently possible to construct. The ages produced by this study for Terraces 2 and 3 of the Test do agree with previous calculations for those Test terraces and their proposed Western Solent correlative (Stanswood Bay and Tom’s Down respectively) within error margins.

8.2 Assessing methodological approaches to constructing long profile projections and correlations

This section summarises methodological approaches to constructing long profile projections and correlations in light of results from this study. It then examines how the revised stratigraphic model for the Solent River system fits contrasting conceptual methods of terrace formation. Both methodological and conceptual approaches to constructing long profile projections of terrace bodies will have an influence on the resulting projections (Chapter 2.3.3). The methods employed in this study (i.e. bedrock contact as base of long profile with gravel thickness making up the defined terrace) were possible due to the expanded sedimentological and stratigraphical dataset collected. Fieldwork carried out in this study highlighted issues relevant to constructing long profile projections based on limited exposures (e.g. Allen and Gibbard 1993) or surface elevations (e.g. the Westaway *et al.* (2006) method). Issues of varying terrace thickness (front to back), post-depositional alterations in terrace surfaces and thicknesses, accuracy of terrace attribution and mapping, and projecting perpendicularly onto a profile line may all affect terrace correlation of borehole records.

A fundamental restriction to producing robust geomorphological terrace models is the volume of data available as highlighted in the example of the Stanswood Bay terrace (Figure 8.1). Results from coastal section recording and GPR surveys carried out in this study emphasise that terrace surfaces are rarely even. The topography of the bedrock platform is often irregular (with or without the presence of significant channels or scours), as are the surfaces of sedimentary units. Surveys indicate that the amplitude of variation of bedrock topography can be significant over short and long spatial scales (at the site level and along terrace landforms). Such large scale and closely-spaced datasets show minor erosional features within a single terrace/climatic stage. GPR survey transect 1 in the Western Solent region 2 (Chapter 5.3.2) for example recorded eight distinct/identifiable bedrock levels (see Figure 5.16) within an area previously mapped with five terraces. This is revised to six terraces in this study. Transect 3, ~1.2 km upstream, recorded ten distinct/identifiable bedrock levels (see Figure 5.18) within an area mapped with five or six terraces depending on the mapping applied; six terraces were recognised in this study. Other instances appear to indicate a gradient from back to front along bedrock surfaces. These results highlight potential problems with determining geomorphological terrace long profiles or correlations without a sufficient dataset to ensure they are representative. Such detail also raises the question of whether data is showing sub-stage variability (i.e. minor erosional episodes within a single stage) and/or evidence of multiple erosional or depositional events per climatic cycle. It is possible that GPR surveys could be used in the future to detect such detail if sufficient depth could be obtained from higher frequency antenna (e.g. Davis and Annan 1989; Vandenberghe and van Overmeeren 1999; Bridge and Lunt 2006; Howard *et al*. 2007; Gibbard *et al*. 2008).

Best practice in constructing long profile projections should incorporate assessment of terrace geomorphology (in terms of location of data on the terrace, e.g. front and back vertical differences and/or changing gravel thicknesses, bluffs, erosional features/processes etc), and accuracy of terrace attribution (e.g. proximity to mapped terrace edge, mapping scale used), with sufficient data coverage to assess localised topographic variation. Such details are necessary in order to ensure that correlative terrace schemes are as robust as possible, as these are issues that may not be detected with desk-based surface elevation methods or sedimentology/lithology-based studies that have limited data points.

8.2.1 Conceptual models of terrace formation

Conceptual approaches to terrace formation may also influence the resulting stratigraphic schemes. Chapter 2.3.1 (see Table 2.2) outlined three models that describe the key terrace forming mechanisms of erosion and aggradation within a single glacial-interglacial climatic cycle. The fundamental differences between the three models are the frequency and timing of downcutting and depositional stages. Bridgland (1994, 1995, 2000, 2001, 2004) proposes the possibility of two terrace forming stages where incision can occur at either cold-warm and/or warm-cold transitional stages, while Gibbard and Lewin (2002; Lewin and Gibbard 2010) recognise a single terrace forming phase predominantly under cold-climate processes. Vandenberghe (1995, 2001, 2008) identifies a single cold-stage depositional phase, but also recognises incision at two phases of the climatic cycle. Vandenberghe (2008) notes that only one of these incision events is usually visible in the fluvial/terrace record however, as the shallow but laterally extensive erosion (at the warm-cold transition) prior to the glacial braided river phase obliterates evidence of the laterally limited erosion in the cold-warm transition and interglacial meandering river phase.

If the aggradation of sands and gravels occurs at the early glacial cooling-limb in addition to the late glacial warming-limb as proposed by Bridgland (2001), coupled with two erosional events per climatic cycle, a terrace could be formed at each transitional stage. In the Solent region/Hampshire Basin this could have been aided by the bedrock of sands and clays that are relatively more easily eroded and have resulted in progressive lateral migration (Westaway *et al*. 2006).

As an exercise to examine how data produced by this study appear in conceptual models of terrace formation the revised Solent stratigraphic scheme (Chapter 8.1, Table 8.3) was applied to two models outlined in Chapter 2.3.1. Table 8.4 shows the sequence of fluvial events during the Pleistocene evolution of the Solent River system alongside the resulting chronology as predicted by those models. Model A is that of Bridgland (1994, 1995, 2000, 2001; Bridgland and Maddy 1995; Bridgland and Allen 1996), while Model B reflects processes proposed by Gibbard and Lewin (2002; Lewin and Gibbard 2010). The MIS model constructed in this study as set out in Table 8.3 is also included for comparison.

The chronologies of the interglacial and associated glacial deposits at Stone Point (Lepe) and Pennington Marshes are used as initial tie-points for the Milford on Sea and Pennington terraces, onto which the subsequent chronology is built using the fluvial phases as set out in each model. It appears that Model A more closely matches current chronological evidence for the evolution of the Solent and its tributaries. The sequence of two potential terrace formation episodes per climatic cycle accounts well for the stratigraphical model of the Solent River system developed in this thesis. The predicted MI stage for the deposition of the Stanswood Bay and Tom's Down terraces fall within the range of OSL dating of those terraces during this study and in the PASHCC project. Assigning an erosional event to both the cold-warm and warm-cold transitional stages of a glacial cycle (Bridgland's Phases 1 and 4 respectively), with subsequent gravel aggradation at separate early glacial (phase 2) and late glacial (phase 5) stages, places the aggradation of Beaulieu Heath/Terrace 5 into MIS 12. The one to one correlation of erosional and depositional phases in the Bridgland model with the sequence of fluvial events in the Solent River system may of course be too simplistic, likely masking a more complex sequence of events. Furthermore as discussed above the geochronology available is questionable, and only indicative of ages for the lower terraces. An expanded chronological framework is needed to resolve the timing of terrace deposition more clearly.

Model B, with a single terrace forming phase, produces an age model which extends back to MIS 22. The predicted MI stage for the deposition of the Stanswood Bay terrace (MIS 8) is at the upper OSL age range for the terrace (MIS 8-6); that of the Tom's Down terraces (MIS 10) falls outside the range of OSL dating of that terrace (MIS 9-8 or 8-7). A single terrace forming stage per glacial cycle would then result in the correlation of Beaulieu Heath/Terrace 5 with MIS 18. The model-produced MIS attributions of terraces showing the first reliable occurrence of handaxes in each region, Sway (Bournemouth), Setley Plain (Western Solent) and Terrace 6 (Test) (Ashton and Hosfield 2010; Ashton *et al.* 2011), with MIS 20, 16 and 20 respectively, similar to current interpretations of the earliest hominin evidence in Britain (Chapter 2.3.3). The Solent River system has recently been interpreted as producing more than one terrace per climatic cycle (Bridgland 2001; Westaway *et al*. 2006) (see Chapter 2.4) but based on limited chronological control.

Using the Bridgland model as described above would imply that the Solent sequence should not develop the 'sandwich' of thin basal cold-climate gravels, interglacial sediments and thicker upper cold-climate gravels as seen in the Lower Thames sequence (Bridgland 1994, 2000; Bridgland and Allen 1996). Such a pattern would be disrupted by the additional erosional phase (4) employed between depositional events. Rather, the Solent sequence should resemble those of (e.g.) the Moselle (Cordier *et al.* 2006), Somme (Antoine *et al.* 2007) and Maas (Van den Berg 1996), with cold-climate, coarse-grained sands and gravels covered by fine-grained interglacial deposits for the first terrace generated per climatic cycle, with the second terrace generated consisting of just the (more substantial) early glacial gravel aggradations. The Solent sequence does not preserve interglacial deposits however, with the exception of the MIS 5e deposits in the Milford on Sea and Pennington terraces (which are then uniquely capped by the subsequent cold-stage gravels). This may indicate that Bridgland's phase 4 erosional stage was substantial during the Middle-Late Pleistocene development of the Solent River system, with each event removing the existing interglacial floodplain deposits. It also indicates that the MIS 5d-a (phase 4) erosional event was either less substantial than those previously or that it occurred later, after the aggradation of the subsequent cold-stage gravels. Alternatively the lack of interglacial sediments may be a function of the acidic bedrock oxidising deposits and preventing preservation. These final points re-emphasises the difficulty in modelling fluvial processes that lead to terrace formation. Despite adapting the Bridgland model to more accurately reflect the Solent sequence (Bridgland 2001), a range of responses are evident in different terraces or locations in the sequence that are not easily modelled or accounted for. It may be the case that there were two phases of erosion (and/or aggradation) for example, but not at the times suggested by Bridgland.

Gibbard and Lewin (2002) contend that the Bridgland model describes rather than explains the relative chronological deposition where interglacial sediments occur in the fluvial sequences of southern Britain. The Bridgland model certainly cannot account completely for the terrace sequence of the Solent River system due to the absence of interglacial sedimentation; as such it cannot be assumed that the model of cold-stage/interglacial/cold-stage depositional sequence is valid. However, it would appear that the two erosional phases in the Bridgland model may have been active in helping to produce the terrace record of the Solent River system.

Table 8.4. The sequence of fluvial events during the Pleistocene evolution of the Solent River system. Key: ✤ Aggradation; ⬇ Downcutting. See Table 8.2 for details of revised MIS model. Terrace nomenclature: HR Holmsey Ridge; SW Sway; BH Beaulieu Heath; SP Setley Plain; MP Mount Pleasant; OM Old Milton; TD Tom's Down; SB Stanswood Bay; MS LG Milford on Sea lower gravel; PN LG Pennington lower gravel; PN M Pennington Marshes interglacial deposits; StP Stone Point interglacial deposits; MS UG Milford on Sea upper gravel; PN UG Pennington upper gravel.

Bournemouth Stour	Bournemouth Solent	Western Solent	Test Valley	Revised MIS model	Terrace Formation Model A (Bridgland)	Predicted MI Stage	Terrace Formation Model B Gibbard & Lewin)	Predicted MI Stage
-	-	✤ HR terrace	✤ Terrace 7	>13	Late glacial [phase 2]	14	Full & late glacial	22
⬇	⬇	⬇	⬇		Late interglacial [phase 4]	13	Early/Full glacial	20
✤ Terrace 13b	✤ SW terrace (Terrace 13b)	✤ SW terrace	✤ Terrace 6	?14/12	Late interglacial/Early glacial [phase 5]	13 to 12	Full & late glacial	20
⬇	⬇	⬇	⬇		Late glacial [phase 1]	12	Early/Full glacial	18
-	-	✤ BH terrace	✤ Terrace 5	?14/12	Late glacial [phase 2]	12	Full & late glacial	18
-	-	⬇	⬇		Late interglacial [phase 4]	11	Early/Full glacial	16
✤ Terrace 13a	✤ SP terrace (Terrace 13a)	✤ SP terrace	?✤ Terrace 4a	?12-9	Late interglacial/Early glacial [phase 5]	11 to 10	Full & late glacial	16
⬇	⬇	⬇	⬇		Late glacial [phase 1]	10	Early/Full glacial	14
✤ Terrace 12	✤ MP terrace (Terrace 12)	✤ MP terrace	?	?12-9	Late glacial [phase 2]	10	Full & late glacial	14
⬇	⬇	⬇	⬇		Late interglacial [phase 4]	9	Early/Full glacial	12
✤ Terrace 11	✤ OM terrace (Terrace 11)	✤ OM terrace	✤ Terrace 4	?12-9	Late interglacial/Early glacial [phase 5]	9 to 8	Full & late glacial	12
⬇	⬇	⬇	⬇		Late glacial [phase 1]	8	Early/Full glacial	10
-	-	✤ TD terrace	✤ Terrace 3	9-7	Late glacial [phase 2]	8	Full & late glacial	10
-	-	⬇	⬇		Late interglacial [phase 4]	7	Early/Full glacial	8
✤ Terrace 10	✤ SB terrace (T10)	✤ SB terrace	✤ Terrace 2	8-6	Late interglacial/Early glacial [phase 5]	7 to 6	Full & late glacial	8
⬇	⬇	⬇	⬇		Late glacial [phase 1]	6	Early/Full glacial	6
✤ Terrace 9	✤ MS (Terrace 9)	✤ MS LG	✤ Terrace 1	6	Late glacial [phase 2]	6	Full & late glacial	6
?✤ [?Terrace 8]	?✤ [?Terrace 8]	✤ PN LG	?	6	Late glacial [phase 2]	6	Full & late glacial	6
		Deposition of PN M organics		5e	Full interglacial [phase 3]	5e	Early to late interglacial	5e
		Deposition of StP organics		5e	Full interglacial [phase 3]	5e	Early to late interglacial	5e
		✤ MS UG		4	Late interglacial/Early glacial [phase 5]	5e to 4	Full & late glacial	4
		✤ PN UG		5d-3	Late interglacial/Early glacial [phase 5]	5e to 4	Full & late glacial	4

8.3 Reinterpreting the terrace stratigraphy as a framework for the Palaeolithic archaeology of the Solent region

The fieldwork, borehole study and OSL dating programme carried out in this study has enabled a reassessment of the stratigraphic sequence in key parts of the Solent River system. A revised stratigraphic scheme has been presented alongside a revised and expanded chronological interpretation, examining the timing and frequency of terrace formation in the Solent region. Together these revised data provide a clearer contextual framework for the extensive archaeological record of the region. A number of implications arise that have a bearing on current interpretations of the archaeology of the Solent, which will enable more rigorous analysis of that resource to be undertaken.

Figure 8.7 shows the locations of sites in the Solent region containing Palaeolithic artefacts, depicted in the revised terrace stratigraphy of the Solent River system.
In total 239 sites are located on Solent terraces examined in this study, with a further 155 in the region located either in smaller tributaries outside the study area or not on a fluvial terrace. Fifty-one more sites are not definitively located on a mapped terrace due to provenance and/or geographical data uncertainties (with ‘general’ and ‘estimated’ coordinate designations). These could potentially be included if they are assumed to originate from the nearest terrace to their given location. Twenty-six of the 239 located sites have had their terrace attribution reassigned by the remapping analysis carried out in this study. Nineteen further sites retain some uncertainty over their terrace attribution due to being located in or near quarried areas (and therefore not on a BGS mapped terrace), but likely terrace attributions can be made with a high degree of probability in most cases. The most significant changes to the context of the archaeology from these 239 locations are due to the revised regional correlations (between Bournemouth, the Western Solent and the Test Valley). Future work will examine the effect that the revised stratigraphy of the Solent River system has had on the context of the archaeological record of the region, and reinterpret the Middle-Late Pleistocene hominin occupation of the Solent.

Table 8.5 shows the revision of terrace attribution for some significant archaeological sites located at Corfe Mullen, Warsash and Dunbridge (as discussed in Chapters 2, 4, 5 and 6) and elsewhere in the region. The revisions proposed by this study have a number of implications for the understanding and interpretation of the archaeological record. Three implications in particularly are of consequence: the broad correlation of elements at either end of the Solent River system, those of the River Stour around Bournemouth and the River Test; the relationship of terraces of the River Test upstream at Dunbridge and downstream at Warsash; and the terrace attributions of individual assemblages in the Warsash area. A re-evaluation of current understandings of the archaeological record of the Solent River system will be necessary in light of the revised stratigraphic, correlative and chronological models produced by this study. An overview of the revised stratigraphic framework can be seen in the transverse sections of the River Stour, Western Solent and River Test terrace staircases in Figure 8.8 below.

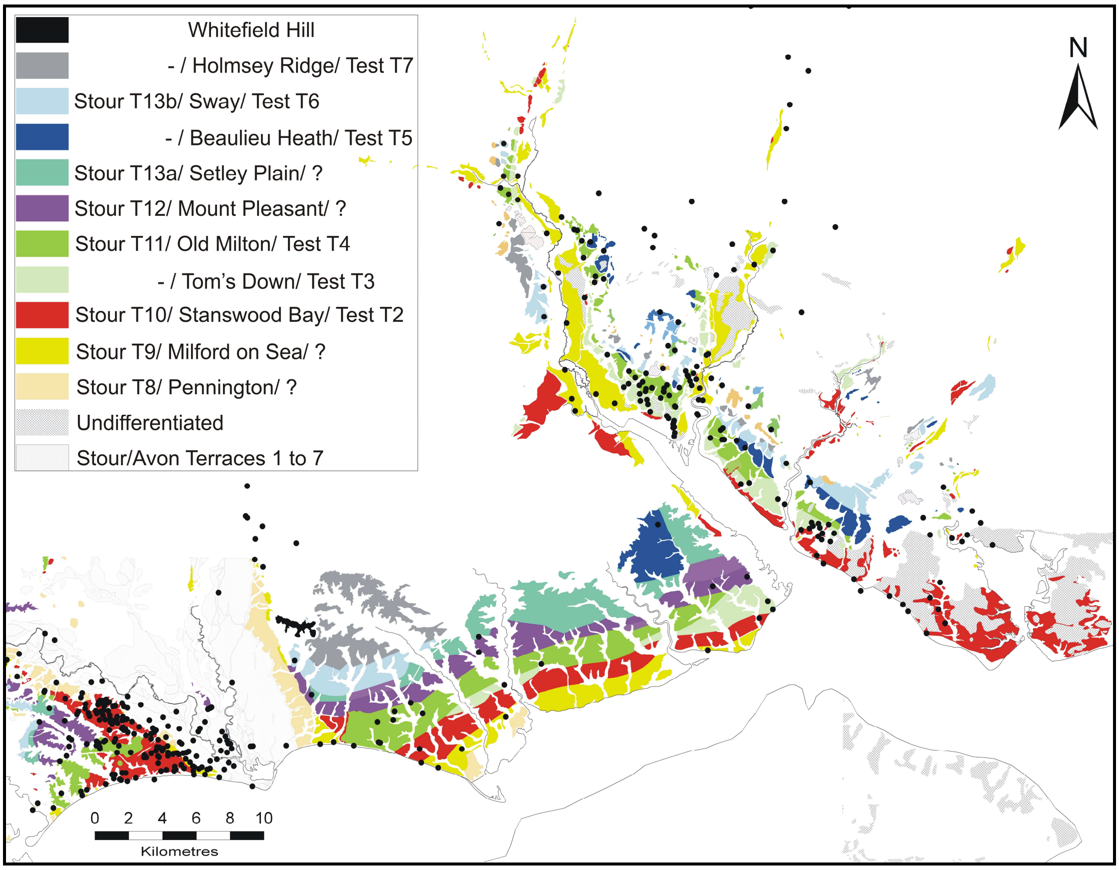


Figure 8.7. Palaeolithic artefact site locations in the revised terrace stratigraphy of the Solent River system.

In the Bournemouth area it has been shown that previous downstream terrace gradients used in correlating with the Western Solent have been too shallow. The revised model proposed here alters terrace correlations of the Bournemouth Solent and Stour deposits. At Corfe Mullen (Table 8.5; Figure 8.8, site 1) sites located in Terrace 12 have yielded nearly 300 handaxes and 88 other artefacts, attributed by downstream correlation with the Setley Plain/Beaulieu Heath terrace (Westaway *et al*. 2006). The revised scheme presented here correlates Terrace 12 of the Stour with the stratigraphically lower Mount Pleasant terrace of the Western Solent. Similarly, the archaeological sites located in other Bournemouth terraces, such as those at King's Park (Table 8.5; Figure 8.8, site 2) and Brixey and Goods Pit, East Howe (Table 8.5; Figure 8.8, site 3), correlate with lower terraces downstream in the Western Solent and Test regions, with Terraces 10 and 9 correlating with Stanswood Bay and Milford on Sea (previously Taddiford Farm and Stanswood Bay respectively). The two most important Western Solent sites, Setley Plain gravel pit and Barton Cliff, retain their attribution to the Setley Plain (Table 8.5; Figure 8.8, site 4) and Old Milton (Table 8.5; Figure 8.8, site 5) terraces respectively. The ten handaxes found at Setley Plain gravel pit are stratigraphically higher than the River Stour sites. The earliest evidence in the Test region, and potentially the region as a whole, are the three handaxes found at Towns Pit, Southampton Common (Table 8.5; Figure 8.8, site 6), which retains its attribution to Terrace 8 here. The upstream correlation of River Test terraces between the Southampton BGS map sheet and the Winchester sheet favoured here results in a reattribution of the Great Copse, Mottisfont artefacts (Table 8.5; Figure 8.8, site 7) from Terrace 7 to Terrace 6. The important site at Dunbridge is attributed to Terrace 4 here (Table 8.5; Figure 8.8, site 8), and downstream the Warsash sites remain in Terraces 3 and 2 (Table 8.5; Figure 8.8, sites 9 and 10) as in previous schemes (Edwards and Freshney 1987; Westaway *et al*. 2006). A closer examination of the Warsash record could potentially reveal a more complex picture however, with the recognition in this study of Terrace 4 deposits in the vicinity.

Table 8.5. Major Palaeolithic artefact site locations as assigned in previous schemes and the revised terrace stratigraphy of the Solent River system. Site location precision key: [A] Accurate; [E] Estimated; [G] General. Artefact numbers key: H Handaxes; L Levallois; O Other. Previous terrace scheme and previous MIS model key: [1] Allen and Gibbard (1993); [2] Westaway *et al.* (2006); [3] PASHCC (Bates *et al*. 2004, 2007; Bates and Briant 2009); [4] Harding *et al*. (2012). Westaway *et al.* (2006)/ Harding *et al*. (2012) terrace nomenclature: Motts/LW: Mottisfont/Lower Warsash; Belbin/UW: Belbin/Upper Warsash. Attributions in **bold** indicate revised terrace correlations and/or MIS age modelling as discussed in the text. * Correlation of Stour terraces are revised as discussed in 8.1.2. Site location and artefact data from Davies (2013).

Site location [Precision]	Artefacts H	L	O	Previous terrace schemes	Prev. MIS model	Revised terrace scheme	Revised MIS model
Corfe Mullen:							
General	75	0	26	Stour Terrace 12 [1,2]	13b [2]	**Stour Terrace 12***	**?12-9**
Railway Ballast Pit [A]	135	1	25				
Sleight Pit [A]	10	0	2				
Cogden Elms Pit [A]	69	0	34				
Brixey and Goods Pit, Redhill Common [A]	10	0	5	Stour Terrace 10 [1,2]	9b	**Stour ?Terrace 8 or 10***	**6 or 8-6**
King's Park:							
Thistlebarrow Pit [A]	110	4	6	Stour Terrace 10 [1,2]	9b	**Stour Terrace 10***	**8-6**
Southern Pit [A]	22		0				
Holdenhurst Rd Pit [A]	8	1	0				
King's Park: General	211	3	34	Stour Terrace 9 or 10 [1,2]	8 or 9b	**Stour Terrace 10***	**8-6**
Brixey and Goods Pit, East Howe [A]	75	3	51	Stour Terrace 8 [1,2]	7b	**Stour Terrace 8***	**6**
Setley Plain gravel pit [A]	10	0	0	Setley Plain		Setley Plain	
Barton Cliff [G]	194	2	29	Old Milton		Old Milton	
Town Pits, [A] Southampton Common	3	0	0	Test Terrace 8		Test Terrace 8	
Great Copse, Mottisfont [A]	1	0	3	Test Terrace 7 [3]	13b [4]	**Test Terrace 6**	?14/12
Chivers Gravel Pit, Romsey Extra [A]	100	3	18	Test Terrace 4		Test Terrace 4	
Belbin's Pit, Romsey Extra [A]	200	3	9	Test Terrace 4		Test Terrace 4	
Dunbridge:							
Dunbridge Hill [A]	1000	5	0	Belbin/UW (T4) [2,4]	9b [4]	**Test Terrace 4**	?12-9
Hatt Hill [E]	1	0	0	Test Terrace 5 [3]			
RMC Gravel Pit [A]	0	0	5				
Kimbridge, Mottisfont [A]	77	0	9	Motts/LW (T3) [2,4] Test Terrace 4 [3]	8 [4]	**Test Terrace 3**	9-7
Warsash: Fleet End Pit [A]	20	13	2	Test Terrace 3 [1,3] Motts/LW (T3) [4]	8 [4]	Test ?Terrace 3/4	9-7 or ?12-9
Warsash: New Pit [A]	8	4	0	Test Terrace 3 [1,3] Motts/LW (T3) [4]	8 [4]	Test ?Terrace 3	?9-7
Warsash:							
Park's Pit [A]	10	0	0	Test Terrace 3 [1,3] Motts/LW (T3) [4]	8 [4]	Test Terrace 3	9-7
Button's Pit [E]	0	0	1				
Dyke's Pit [A]	2	0	0				
Hook Lane [G]	1	0	0				
Warsash: General	176 200	4 13	98 0	Test Terrace 2/3 [1,3] Hamble(T2)/ Motts/LW (T3) [4]	6 and 8 [4]	Test Terrace 2 & 3	**8-6** and 9-7
Warsash: Pyramid Sand and Gravel Pit [A]	73	0	2	Test Terrace 2 [1,3] Hamble (T2) [2,4]	6 [4]	Test ?Terrace 2/3	**8-6 or 9-7**
Warsash : Newbury's Pit [A]	6	0	1	Test Terrace 3 [1,3] Motts/LW (T3) [4]	8 [4]	**Test Terrace 2**	**8-6**

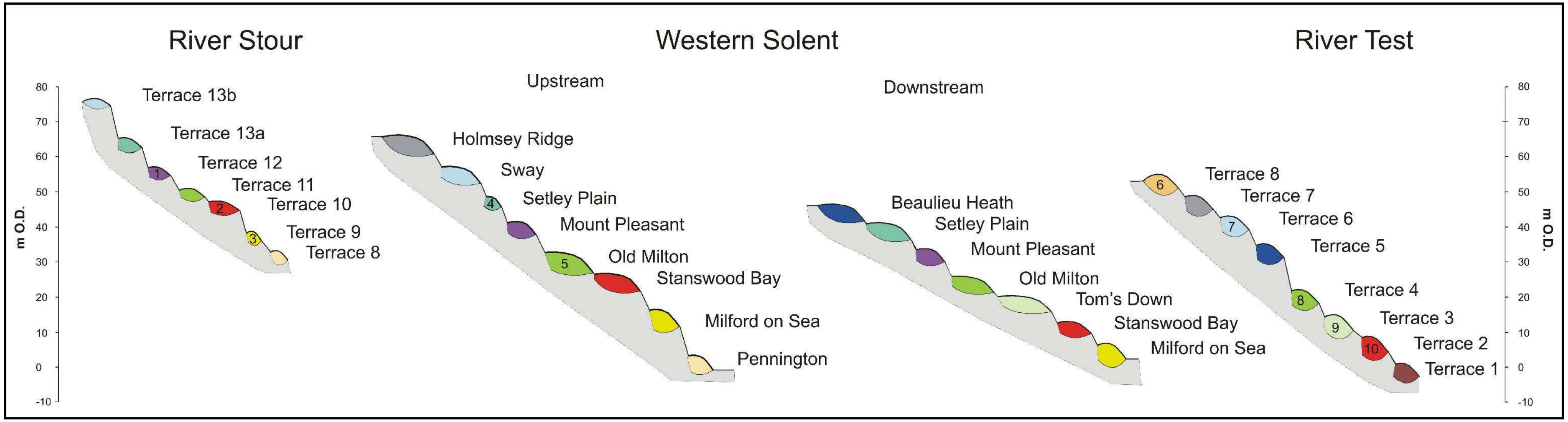


Figure 8.8. Idealised transverse sections of the River Stour, Western Solent and River Test terrace staircases, with the locations of some important archaeological sites discussed in the text. The River Stour profile is representative of the upstream end (from around Corfe Mullen) due to the better developed and more complete stratigraphy there. The Western Solent is shown upstream at Christchurch Bay and downstream at Stanswood Bay to show the full stratigraphic sequence. The River Test profile is representative of the downstream end between the tributary Rivers Itchen and Hamble due to the better developed and more complete stratigraphy there. Archaeological sites key: 1. Corfe Mullen; 2. King's Park; 3. Brixey and Goods Pit, East Howe; 4. Setley Plain gravel pit; 5. Barton Cliff; 6. Town's Pit, Southampton Common; 7. Great Copse, Mottisfont; 8. Dunbridge; 9. Warsash (various, see table 8.5 for details); 10. Warsash (various, see table 8.5 for details).

CHAPTER NINE: CONCLUSIONS

This study has produced revised terrace stratigraphies for three key areas of the Solent River system, the River Test, the Western Solent and the River Stour, based upon an extensive and robust set of data. These three areas are important as they represent the chronostratigraphic framework for understanding the Palaeolithic archaeology of the Solent region. Geomorphological subdivision of the terrace sequence has been carried out after careful assessment of long profiles of stratigraphic data collected from boreholes, new fieldwork and previous studies in the region. Correlations upstream into the Stour and downstream into the Test have been based on terrace gradients constructed using spatially extensive bedrock profiles from the revised Western Solent stratigraphy.

Four main conclusions can be drawn from this study. Firstly, the collation and generation of new stratigraphic data and its application to previous models of the Solent River system highlights inconsistencies within those models. The stratigraphic schemes of Allen and Gibbard (1993) and Westaway *et al*. (2006)/Harding *et al*. (2012) have therefore been revised to produce a new stratigraphic model to incorporate the expanded dataset. Secondly the revised stratigraphy of the region produced here has clarified correlations within and between the major elements of the Solent system, producing a more robust framework for the Palaeolithic archaeological record of the region. The study has also contributed to the most robust chronological model for the Solent that it is presently possible to suggest. Thirdly, the revised stratigraphic scheme has implications for understanding the archaeological record of the region. Revisions to the terrace stratigraphy have clarified the relationship between the River Test sites at Dunbridge and Warsash and proposed correlation across the region. The earliest archaeological sites in the study area with secure provenance would appear to be those of Towns Pit, Southampton Common (Test Terrace 8) and Great Copse, Mottisfont (Test Terrace 6) in the Test valley. In the Western Solent the earliest site is at Setley Plain gravel pit, one terrace below that at Great Copse. The earliest evidence in the River Stour is found at the sites around Corfe Mullen (Stour Terrace 12), one terrace below Setley Plain.

Finally the study has highlighted broader methodological issues that remain in both the use of the OSL method in the Solent region and the construction of long profile projections of terraces generally. The OSL dating programme conducted for this study demonstrated the complicated nature of the fluvial sediments of the Solent River system based on the application of a comprehensive suite of tests. Where rigorous test procedures have not been applied in previous studies the ages produced should be treated with some caution. Similarly, the construction of revised stratigraphic frameworks requires careful assessment of the data. Where the use of geomorphological methods are necessary, such as in the Solent region, it has been shown that the data used to define and correlate terraces will impact the resulting stratigraphic model. Uncertainties may be mitigated, to a degree, by the availability of sufficient closely-spaced data to enable confidence in the representative nature of data-points within a terrace landform. Stratigraphic and correlative models should ideally be based on lithological, biostratigraphical and/or chronological interpretation, but where this is not possible or practical then geomorphological data used should be carefully assessed.

The long profile terrace stratigraphies, gradients and correlative models produced by this study have revised previous schemes of the Solent River and its tributaries, the River Stour and River Test. The study has also proposed system-wide correlation of archaeologically important areas for the first time, enabling more detailed interrogation of Middle-Late Pleistocene hominin settlement history and technology. However, more detailed chronological control is still required for the terrace stratigraphy in order to further refine the model presented here for the evolution of the Solent River system and the archaeological record it contains.

REFERENCES

Aitken, M.J. 1985. *Thermoluminescence Dating*. Academic Press: London.

Aitken, M.J. 1998. *An Introduction to Optical Dating*. Oxford University Press: Oxford.

Allen, L.G. 1991. *The evolution of the Solent River system during the Pleistocene*. Unpublished PhD Thesis, Cambridge University.

Allen, L.G., Gibbard, P.L. 1993. Pleistocene evolution of the Solent River of southern England. *Quaternary Science Reviews* **12**, pp.503 – 528.

Allen, L.G., Gibbard, P.L., Pettit, M.E., Preece, R.C., Robinson, J.E. 1996. Late Pleistocene interglacial deposits at Pennington Marshes, Lymington, Hampshire, southern England. *Proceedings of the Geologists' Association* **107**, pp. 39 – 50.

Antoine, P. 1994. The Somme Valley terrace system (northern France); a model or river response to Quaternary climatic variations since 800,000 BP. *Terra Nova* **6**, pp. 453 – 464.

Antoine, P., Lautridou, J.P., Laurent, M. 2000. Long-term fluvial archives in NW France: response of the Seine and Somme rivers to tectonic movements, climate variations and sea-level changes. *Geomorphology* **33**, pp. 183 – 207.

Antoine, P., Coutard, J.-P., Gibbard, P., Hallegouet, B., Lautridou, J.-P., Ozouf, J.-C. 2003. The Pleistocene rivers of the English Channel region. *Journal of Quaternary Science* **18**, pp. 227 – 243.

Antoine, P., Lozouet, N.L., Chausse´ , C., Lautridou, J.-P., Pastre, J.-F., Auguste, P., Bahain, J.-J., Falgue` res, C., Galehb, B., 2007. Pleistocene fluvial terraces from northern France (Seine, Yonne, Somme): synthesis and new results from interglacial deposits. *Quaternary Science Reviews* **26**, pp. 2701 – 2723.

Arcone, S.A., Lawson, D.E., Delaney, A.J., Strasser, J.C., Strasser, J.D. 1998. Ground-penetrating radar reflection profiling of groundwater and bedrock in an area of discontinuous permafrost. *Geophysics* **63**, pp. 1573 – 1584.

Arribas, A. and Palmqvist, P. 2002. The first human dispersal to Europe: remarks on the archaeological and palaeoanthropological record from Orce (Guadix-Baza basin, southeastern Spain). *Human Evolution* **17**, no. 1-2, pp. 55 – 78.

Arzarello, M. and Peretto, C., 2010. Out of Africa: the first evidence of Italian peninsula occupation. *Quaternary International* **223 – 224**, pp. 65 – 70.

Arzarello M., Marcolini, F., Pavia, G., Pavia, M., Petronio, C., Petrucci, M., Rook, L., Sardella, R. 2007. Evidence of earliest human occurrence in Europe: The site of Pirro Nord (Southern Italy). *Naturwissenschaften* **94**, pp. 107 – 112.

Arzarell, M., Pavia, G., Peretto, C., Petronio, C., Sardella, R. 2012. Evidence of an Early Pleistocene hominin presence at Pirro Nord (Apricena, Foggia, southern Italy): P13 site. *Quaternary International* **267**, pp. 56 – 61.

Ashton, N., Hosfield, R. 2010. Mapping the human record in the British early Palaeolithic: evidence from the Solent River system. *Journal of Quaternary Science* **25**, pp. 737 – 753.

Ashton, N.M., Lewis, S.G. 2002. Deserted Britain: declining populations in the British late Middle Pleistocene. *Antiquity* **76**, pp. 388 – 396.

Ashton NM, Lewis SG, Hosfield RT. 2011. Mapping the human record: population change in Britain during the later Middle Pleistocene. In *The Ancient Human Occupation of Britain*, Ashton N.M., Lewis S.G., Stringer C.B. (eds). Elsevier: Amsterdam, pp. 39 – 53.

Ashton, N.M., Lewis, S.G., Parfitt, S.A., Penkman, K.E.H., Coope, G.R. 2008. New evidence for complex climate change in MIS 11 from Hoxne, UK. Quaternary Science Reviews 27, pp. 652 – 668.

Ashton, N.M., Parfitt, S.A., Lewis, S.G., Coope, G.R., Larkin, N., 2008. Happisburgh site 1 (TG388307). In *The Quaternary of Northern East Anglia*, Candy, I., Lee, J.R., Harrison, A.M. (eds.). Quaternary Research Association: Cambridge, pp. 151 – 156.

Bailey, R.M. and Arnold, L.J. 2006. Statistical modelling of single grain quartz D_e distributions and an assessment of procedures for estimating burial dose. *Quaternary Science Reviews* **25**, pp. 2475 – 2502.

Barton, C.M., Hopson, P.M., Newell, A.J., Royse, K.R. 2003. Geology of the Ringwood district – a brief explanation of the geological map. *Sheet Explanation of the British Geological Survey*, 1:50,000 Sheet 314 Ringwood (England and Wales).

Bates, M.R., Briant, R.M. 2009. Quaternary sediments of the Sussex/Hampshire Coastal Corridor: a brief overview. In *The Quaternary of the Solent Basin and West Sussex Raised Beaches: Field Guide*, Briant, R.M., Bates, M.R., Hosfield, R.T., Wenban-Smith, F.F. (eds). Quaternary Research Association: London, pp. 21 – 41.

Bates, M.R., Wenban-Smith, F.F., Briant, R., Marshall, G. 2004. *Palaeolithic Archaeology of the Sussex/Hampshire Coastal Corridor: project number 3279*. Unpublished report for English Heritage.

Bates, M.R., Briant, R.M., Wenban-Smith, F.F., Bates, C.R. 2007. Curation of the Sussex/Hampshire Coastal Corridor Lower/Middle Palaeolithic Record. Project Report – English Heritage ALSF Project 3279.

Bates, M.R., Briant, R.M., Rhodes, E.J., Schwenninger, J.-L., Whittaker, J.E. 2010. A new chronological framework for Middle and Upper Pleistocene landscape evolution in the Sussex/Hampshire Coastal Corridor. *Proceedings of the Geologists' Association* **121**, pp. 369 – 392.

Best, J.L., Ashworth, P.J., Bristow, C.S., Roden, J. 2003. Three-dimensional sedimentary architecture of a large, mid-channel sand braid bar, Jamuna River, Bangladesh. *Journal of Sedimentary Research* **73**, pp. 516 – 530.

Birkhead, A.L., Heritage, G.L., White, H., van Niekerk, A.W. 1996. Ground-penetrating radar as a tool for mapping the phreatic surface, bedrock profile, and alluvial stratigraphy in the Sabie River, Kruger National Park. *Journal of Soil and Water Conservation* **51**, pp. 234 – 241.

Blum and Törnqvist 2000. Fluvial responses to climate and sea-level change: a review and look forward. *Sedimentology*, **47** (Suppl. 1), pp. 2 – 48.

Boenigk, W. and Frechen, M. 2006. The Pliocene and Quaternary fluvial archives of the Rhine system. *Quaternary Science Reviews.* 25, pp. 550 – 574.

Booth, K.A. 2002. Geology of the Winchester district – a brief explanation of the geological map. *Sheet Explanation of the British Geological Survey*, 1:50,000 Sheet 299 Winchester (England and Wales).

Böse, M., Lüthgens, C., Lee, J.R., Rose, J. 2012. Quaternary glaciations of northern Europe. *Quaternary Science Reviews* **44**, pp. 1 – 25.

Boswell, K.C., Green, J.F.N., 1946. A detailed profile of the River Test. *Proceedings of the Geologists' Association* **57**, pp.102 – 116.

Bourdier, F. 1958. Origine et success d'une theorie geologique illusoire: l'eustatisme appliqué aux terrasses alluviales. *Revue de Geomorphologie Dynamique*, pp. 16 – 19.

Briant RM. 2002. Fluvial responses to rapid climate change in eastern England during the last glacial period. Unpublished PhD thesis, University of Cambridge

Briant, R.M., Bates, M.R., Schwenninger, J-L. Wenban-Smith, F.F. 2006. An optically stimulated luminescence dated Middle to Late Pleistocene fluvial sequence from the western Solent Basin, southern England. *Journal of Quaternary Science* **21**, pp. 507 – 523.

Briant, R.M., Bates, M.R., Hosfield, R.T., Wenban-Smith, F.F. (eds). 2009a. *The Quaternary of the Solent Basin and West Sussex Raised Beaches: Field Guide*, Quaternary Research Association: London.

Briant, R.M., Wenban-Smith, F.F., Schwenninger, J.-L. 2009b. Solent river gravels at Barton on Sea, Hampshire SZ 230 930. In *The Quaternary of the Solent Basin and West Sussex Raised Beaches: Field Guide*, Briant, R.M., Bates, M.R., Hosfield, R.T., Wenban-Smith, F.F. (eds). Quaternary Research Association: London, pp. 171 – 188.

Briant, R.M., Bates, M.R., Boreham, S., Cameron, N.G., Coope, G.R., Field, M.H., Keen, D.H., Simons, R.M.J., Schwenninger, J-L., Wenban-Smith, F.F., Whitaker, J.E. 2009c. Gravels and interglacial sediments at Stone Point Site of Special Scientific Interest, Lepe Country Park, Hampshire. In *The Quaternary of the Solent Basin and*

West Sussex Raised Beaches: Field Guide, Briant, R.M., Bates, M.R., Hosfield, R.T., Wenban-Smith, F.F. (eds). Quaternary Research Association: London, pp. 171 – 188.

Briant, R.M., Bates, M.R., Marshall, G.D., Schwenninger, J-L., Wenban-Smith, F.F. 2012. Terrace reconstruction and long profile projection: a case study from the Solent river system near Southampton, England. *Proceedings of the Geologists' Association*

Briant, R.M., Bates, M.R., Boreham, S., Coope, R.G., De Schepper, S., Field, M.H., Wenban-Smith, F.F., Whitaker, J, E. 2013. Palaeoenvironmental reconstruction from a decalcified Interglacial sequence at St Leonard's Farm, Hampshire, England. *Quaternary Newsletter* Volume **130**, pp. 21 – 40.

Bridge, J.S., Lunt, I.A. 2006. Depositional models of braided rivers. In *Braided Rivers: Process, Deposits, Ecology and Management*, Sambrook Smith, G.H., Best, J.L., Bristow, C.S., Petts, G.E. (eds.). Blackwell: Oxford, pp. 11 – 50.

Bridgland, D.R. 1994. *The Quaternary of the Thames*. Chapman & Hall: London. 441 pp.

Bridgland, D.R. 1995. The Quaternary sequence of the eastern Thames basin: problems of correlation. In *The Quaternary of the Lower Reaches of the Thames, Field Guide*, Bridgland, D.R., Allen, P. and Haggart, B.A. (eds). Quaternary Research Association: Durham, pp. 35 – 52.

Bridgland, D.R. 1996. Quaternary river terrace deposits as a framework for the Lower Palaeolithic record. In *The English Palaeolithic Reviewed*. Wessex Archaeology, Gamble, C.S., Lawson, A.J. (eds.). Salisbury, pp. 23 – 39.

Bridgland, D.R. 2000. River terrace systems in north-west Europe: an archive of environmental change, uplift and early human occupation. *Quaternary Science Reviews*, **19**, pp. 1293 – 1303.

Bridgland, D.R. 2001. The Pleistocene evolution and Palaeolithic occupation of the Solent River. In *Palaeolithic Archaeology of the Solent River*, Wenban-Smith, F.F., Hosfield, R.T. (eds). Occasional Paper 7, Lithic Studies Society: Southampton, pp. 15 – 25.

Bridgland, D.R. 2006. The Middle and Upper Pleistocene sequence in the Lower Thames: a record of Milankovitch climatic fluctuation and early human occupation of southern Britain. *Proceedings of the Geologists' Association* **117**, pp. 281 – 305.

Bridgland, D.R., Allen, P. 1996.A revised model for terrace formation and its significance for the lower Middle Pleistocene Thames terrace aggradations of north-east Essex, UK. In *The Early Middle Pleistocene in Europe*, Turner, C. (ed). Balkema: Rotterdam, pp. 121 – 134.

Bridgland, D.R., Harding, P. 1987. Palaeolithic sites in tributary valleys of the Solent River. In *Wessex and the Isle of Wight: Field Guide*, Barber, K.E. (ed.). The Quaternary Research Association: Cambridge, pp. 45 – 57.

Bridgland, D.R., Maddy, D. 1995. River Terraces as records of Quaternary Climate Oscillation. *Programme with Abstracts. INQUA XIV. Berlin, 37.*

Bridgland, D., Westaway, R. 2008a. Climatically controlled river terrace staircases: A worldwide Quaternary phenomenon. *Geomorphology* **98,** pp. 285 – 315.

Bridgland, D.R., Westaway, R., 2008b. Preservation patterns of late Cenozoic fluvial deposits and their implications. Results from IGCP 449. *Quaternary International* **189**, pp. 5 – 38.

Bridgland, D.R., Schreve, D.C., Keen, D.H., Meyrick, R., Westaway, R. 2004. Biostratigraphical correlation between the late Quaternary sequence of the Thames and key fluvial localities in Central Germany. *Proceedings of the Geologists' Association* **115**, pp. 125 – 140.

Bristow, C.R., Freshney, E.C., Penn, I.E. 1991. *Geology of the Country around Bournemouth: Memoir for 1:50,000 Geological Map Sheet 329 (England and Wales)*. HMSO: London.

British Geological Survey. 2009a – h. Sheets 298 (Salisbury), 299 (Winchester), 314 (Ringwood), 315 (Southampton), 316 (Fareham), 328 (Dorchester), 329 (Bournemouth) and 331 (Portsmouth) in Digital Geological Map of Great Britain 1:50 000 scale (DiGMapGB-50) data [CD-Rom]. Version 5.18. British Geological Survey: Keyworth, Nottingham.

Bromley, M.H. 1991a. Architectural features of the Kayenta Formation (Lower Jurassic), Colorado Plateau, USA: relationship to salt tectonics in the Paradox Basin. *Sedimentary Geology* **73**, pp. 77 – 99.

Bromley, M.H. 1991b. Variations in fluvial style as revealed by architectural elements, Kayenta Formation, Mesa Creek, Colorado, USA: evidence for both ephemeral and perennial fluvial processes. In *The Three-dimensional Facies Architect of Terrigenous Clastic Sediments and its Implications for Hydrocarbon Discovery and Recovery*, Miall, A.D. and Tyler, N. (eds). Society of Economic Paleontologists and Mineralogists, Concepts in Sedimentology and Paleontology Vol. 3, pp. 94 – 102.

Brown, R.C., Gilbertson, D.D., Green, C.P., Keen, D.H., 1975. Stratigraphy and environmental significance of Pleistocene deposits at Stone, Hampshire. *Proceedings of the Geologists' Association* **86**, pp. 349 – 363.

Brown, P., Sutikna, T., Morwood, M.J., Soejono, R.P., Jatmiko, Wayhu Saptomo, E., and Rokus Awe Due. 2004. A new small-bodied hominin from the Late Pleistocene of Flores, Indonesia. *Nature* **431**, pp. 1055 – 1061.

Brown, A.G., Basell, L.S., Toms, P.S., Scrivener, R.C. 2009. Towards a budget approach to Pleistocene terraces: preliminary studies using the River Exe in South West England, UK. *Proceedings of the Geologists' Association* **120**, pp. 275 – 281.

Brown, A.G., Basell, L.S., Toms, P.S., Bennett, J., Hosfield, R.T., Scrivener, R.C. 2010. Later Pleistocene evolution of the Exe valley: a chronostratigraphic model of terrace formation and its implications for Palaeolithic archaeology. *Quaternary Science Reviews* **29**, pp. 897 – 912.

Bull, W.B. 1991. *Geomorphic Responses to Climatic Change*. Oxford University Press: Oxford, 326 pp.

Burkitt, M.C., Paterson, T.T., Mogridge, C.J. 1939. The Lower Palaeolithic industries near Warsash, Hampshire. *Proceedings of the Prehistoric Society* **5**, pp. 39 – 50.

Bury, H. 1923. Some aspects of the Hampshire plateau gravels. *Proceedings of the Prehistoric Society of East Anglia* **4**, pp. 15 – 41.

Bury, H. 1925. The Bournemouth Plateau and its palaeoliths. *Proceedings of the Bournemouth Natural Sciences Society* **16**, pp. 72 – 81.

Calkin, J.B., Green, J.F.N., 1949. Palaeoliths and terraces near Bournemouth. *Proceedings of the Prehistoric Society* **15**, pp. 21 – 37.

Candy, I., Schreve, D.C. 2007. Land–sea correlation of Middle Pleistocene temperate sub-stages using high-precision uranium-series dating of tufa deposits from southern England. *Quaternary Science Reviews* **26**, pp. 1223 – 1235.

Carbonell, E., Bermu´ dez de Castro, J.M., Arsuaga, J.L., Diez, J.C., Rosas, A., Cuenca-Bescos, G., Sala, R., Mosquera, M., Rodriguez. X.P. 1995. Lower Pleistocene hominids and artefacts from Atapuerca-TD6 (Spain). *Science* **269**, pp. 826 – 829.

Carbonell, E., Bermúdez de Castro, J.M., Parés, J.M., Pérez-González, A., Cuenca-Bescós, G., Ollé, A., Mosquera, M., Huguet, R., van der Made, J., Rosas, A., Sala, R., Vallverdú, J., García, N., Granger, D.E., Martinón-Torres, M., Rodríguez, X.P., Stock, G.M., Vergès, J.M., Allué, E., Burjachs, F., Cáceres, I., Canals, A., Benito, A., Díez, C., Lozano, M., Mateos, A., Navazo, M., Rodríguez, J., Rosell, J., Arsuaga, J.L. 2008. The first hominin of Europe. *Nature* **452**, pp. 465 – 470.

Cardenas, M.B., Zlotnik, V.A. 2003. Three-dimensional model of modern channel bend deposits. *Water Resources Research* **39 (6)**, 1141, doi:10.1029/2002WR001383

Clarke, M.R. 1981. The Sand and Gravel Resources of the Country North of Bournemouth, Dorset. Description of Parts of 1:25,000 Sheets SU 00, 10, 20, SZ 09, 19 and 29. In *Institute of Geological Sciences Mineral Assessment Report 51*. HMSO: London.

Clark, C. E., Gibbard, P. L., Rose, J. 2004. Glacial limits in the British Isles. In *Extent and Chronology of Glaciation. Volume 1. Europe*, Ehlers, J., Gibbard, P. L. (eds.). Elsevier Science: Amsterdam, pp. 47 – 82.

Clayton, K.M. 1977. River terraces. In *British Quaternary Studies, Recent Advances*, Shotton, F.W. (ed). Oxford University Press: Oxford, pp. 153 – 168.

Clemente, P., Pérez-Arlucea, M. 1993. Depositional architecture of the Cuerda del Pozo Formation, Lower Cretaceous of the extensional Cameros Basin, north-central Spain. *Journal of Sedimentary Petrology* **63**, pp. 437 – 452.

Codrington, T. 1870. On the superficial deposits of the south of Hampshire and the Isle of Wight. *Quarterly Journal of the Geological Society of London* **26**, pp. 528 – 551.

Cohen, K.M., MacDonald, K., Joordens, J.C.A., Roebroeks, W., Gibbard, P.L. 2012. The earliest occupation of north-west Europe: a coastal perspective. *Quaternary International* **271**, pp.70 – 83.

Colls, A.E., Stokes, S., Blum, M.D., Straffin, E. 2001: Age limits on the Late Quaternary evolution of the upper Loire River. *Quaternary Science Reviews* **20**, pp. 743 – 750.

Corbeanu, R.M., Soegaard, K., Szerbiak, R.B., Thurmond, J.B., McMechan, G.A., Wang, D., Snelgrove, S., Forster, C.B., Menitove, A. 2001. Detailed internal architecture of a fluvial sandstone determined from outcrop, cores, and 3-D ground penetrating radar: example from the middle Cretaceous Ferron Sandstone, east–central Utah. *AAPG Bulletin* **85**, pp.1583 – 1608.

Cordier, S., Harmand, D., Frechen, M., Beiner, M., 2006. Fluvial system response to Middle and Upper Pleistocene climate change in the Meurthe and Moselle valleys (Paris basin and Rhenish Massif). *Quaternary Science Reviews* **25**, pp.1460 – 1474.

Cowan, E.J. 1991. The large-scale architecture of the fluvial Westwater Canyon Member, Morrison Formation (Jurassic), San Juan Basin, New Mexico. In *The Three-dimensional Facies Architect of Terrigenous Clastic Sediments and its Implications for Hydrocarbon Discovery and Recovery*, Miall, A.D. and Tyler, N. (eds). Society of Economic Paleontologists and Mineralogists, Concepts in Sedimentology and Paleontology Vol. 3, pp. 80 – 93.

Currant, A.P. 1989. The Quaternary origins of the modern British mammal fauna. *Biological Journal of the Linnean Society* **38**, pp. 22 – 30.

Davies, R. 2013. Palaeolithic Archaeology of the Solent River: Human Settlement History and Technology. Unpublished PhD thesis. University of Reading.

Davis, J.L., Annan, A.P., 1989. Ground-penetrating radar for high-resolution mapping of soil and rock stratigraphy. *Geophysical Prospecting* **37**, pp. 531 – 551.

Darwin-Fox, W. 1862. When and how was the Isle of Wight severed from the mainland? *The Geologist* **5**, pp. 452 – 454.

DeCelles, P.G., Gray, M.B., Ridgway, K.D., Cole, R.B., Pivnik, D.A., Pequera, N., Srivastava, P. 1991. Controls on synorogenic alluvial-fan architecture, Beartooth Conglomerate (Paleocene), Wyoming and Montana. *Sedimentology* **72**, pp. 225 – 252.

Dennell, R. 2003. Dispersal and colonisation, long and short chronologies: how continuous is the Early Pleistocene record for hominids outside Africa? *Journal of Human Evolution* **45**, pp. 421 – 440.

Dennell, R., Roebroeks, W. 1996. The earliest colonization of Europe: the short chronology revisited. *Antiquity* **70**, pp. 535 – 542.

Dominic, D.F., Egan, K., Carney, C., Wolfe, P.J., Boardman, M.R. 1995. Delineation of shallow stratigraphy using ground penetrating radar. *Journal of Applied Geophysics* **33**, pp. 167 – 175.

Duller, G.A.T. 2008. Luminescence dating of Quaternary sediments: recent advances. *Journal of Quaternary Science*, **19** (2), pp. 183 – 192.

Edwards, R.A., Freshney, E.C. 1987. Geology of the Country around Southampton. *Memoir for 1:50,000 Geological Map Sheet 315 (England and Wales)*. HMSO: London.

Evans, J. 1864. On some recent discoveries of flint implements in drift deposits in Hampshire. *Quarterly Journal of the Geological Society of London* **20**, pp. 188 – 194.

Everard, C.E. 1952. *A contribution to the geomorphology of south Hampshire and the Isle of Wight*. M.Sc. thesis, University of Southampton.

Everard, C.E. 1954. The Solent River, a geomorphological study. *Transactions of the Institute of British Geographers* **26**, pp. 41 – 58.

Everard 1956. Erosional platforms of the borders of the Hampshire Basin. *Transactions of the Institute of British Geographers* **22**, pp. 33 – 46.

Everard 1957. The streams of the New Forest: a study in drainage evolution. *Proceedings of the Hampshire Field Club* **19**, pp. 240 – 252.

Falguères, C. 2003. ESR dating and the human evolution: contribution to the chronology of the earliest humans in Europe. *Quaternary Science Reviews* **22**, pp. 1345 – 1351.

Ferring, R., Omsb, O., Agustíc, J., Bernad, F., Nioradzee, M., Sheliae, T., Tappenf, M., Vekuae, A., Zhvaniae, D., Lordkipanidzee, D. 2011. Earliest human occupations at Dmanisi (Georgian Caucasus) dated to 1.85–1.78 Ma. www.pnas.org/cgi/doi/10.1073/pnas.1106638108.

Fisher, S.C., Stewart, R.R., Jol, H.M. 1996. Ground penetrating radar (GPR) data enhancement using seismic techniques. Journal of Environmental Engineering and Geophysics **1**, pp. 89 – 96.

Fuchs, M., Woda, C., Bürkert, A. 2007. Chronostratigraphy of a sediment record from the Hajar mountain range in the north Oman: Implications for optical dating of insufficiently bleached sediments. *Quaternary Geochronology* **2**, pp. 202 – 207.

Gabunia L., Vekua, A. 1995. A Plio-Pleistocene hominid from Dmanisi, East Georgia, Caucasus. *Nature* **373**, pp. 509 – 512.

Gabunia, L., Vekua, A., Lordkipanidze, D., Swisher III, C.C., Ferring, R., Justus, A., Nioradze, M., Tvalchrelidze, M., Antón, S.C., Bosinski, G., Jöris, O., de Lumley, M.-A., Majsuradze, G., Mouskhelishvili, A. 2000. Earliest Pleistocene hominid cranial remains from Dmanisi, Republic of Georgia: Taxonomy, geological setting, and age. *Science* **288**, pp. 1019 – 1025.

Gamble, C.S. 1986. *The Palaeolithic settlement of Europe*. Cambridge University Press, Cambridge.

Gamble, C.S. 1992. Comment on Roebroeks, W., Conard, N.J., van Kolfschoten. T. Dense forests, cold steppes and the Palaeolithic settlement of northern Europe. *Current Anthropology* **33**.

Gibbard, P.L. 1985. *The Pleistocene history of the Middle Thames Valley.* Cambridge University Press: Cambridge.

Gibbard, P.L. 1994. *Pleistocene history of the Lower Thames.* Cambridge University Press: Cambridge.

Gibbard, P.L. 1995. The formation of the Strait of Dover. In *Island Britain: A Quaternary Perspective*, Preece, R.C. (ed). Special Publication 96, Geological Society: London, pp. 15 – 26.

Gibbard, P.L. 2007. Palaeogeography: Europe cut adrift. *Nature* **448**, pp.259-260.

Gibbard, P.L., Allen, L.G. 1995. Drainage evolution in south and east England during the Pleistocene. *Terra Nova* **6**, pp. 444 – 452.

Gibbard, P.L., Clark, C.D., 2011. Pleistocene glaciation limits in Great Britain. In *Quaternary Glaciation Extent and Chronology: A Closer Look*, Ehlers, J., Gibbard, P.L., Hughes, P.D. (eds.). Elsevier: Amsterdam, pp. 75 – 93.

Gibbard, P.L., Lewin, J. 2002. Climate and related controls on interglacial sedimentation in lowland Britain. *Sedimentary Geology* **151**, pp. 187 – 210.

Gibbard, P.L., West, R.G., Pasanen, A., Wymer, J.J., Boreham, S., Cohen, K.M., Rolfe, C. 2008. Pleistocene geology of the Palaeolithic sequence at Redhill, Thetford, Norfolk, England. *Proceedings of the Geologists' Association* **119**, pp. 175 – 192.

Green, C.P., Keen, D.H. 1987. Stratigraphy and palaeoenvironments of the Stone Point deposits: the 1975 investigation. In *Wessex and the Isle of Wight: Field Guide*, Barber, K.E. (ed.). The Quaternary Research Association: Cambridge, pp. 17 – 20.

Green, C.P., McGregor, D.F.M. 1980. Quaternary evolution of the River Thames. In *The Shaping of Southern England*, Jones, D.K.C. (ed). Institute of British Geographers Special Publication, no. 11. Academic Press: London, pp. 177 – 202.

Green, C.P., McGregor, D.F.M. 1983. Lithology of the Thames gravels. In *Diversion of the Thames: Field Guide*, Rose, J. (ed). Quaternary Research Association: Cambridge, pp. 24 – 38.

Green, C.P., McGregor, D.F.M. 1987. River terraces: a stratigraphic record of environmental change In *International Geomorphology 1986. Proceedings 1st conference. Vol. 1*, Gardiner, V. (ed). Wiley & Sons: London, pp. 977 – 987.

Green, C.P., McGregor, D.F.M., Evans, A.H. 1982. Development of the Thames drainage system in Early and Middle Pleistocene times. *Geological Magazine* **119** (3), pp. 281 – 290.

Green, J.F.N., 1936. The terraces of southernmost England. *Quarterly Journal of the Geological Society of London* **92**, pp. 58 – 88.

Green, J.F.N., 1943. The age of the raised beaches of south Britain. *Proceedings of the Geologists' Association* **54**, pp. 129 – 140.

Green, J.F.N., 1946. The terraces of Bournemouth, Hants. *Proceedings of the Geologists' Association* **57**, pp. 82 – 101.

Green, J.F.N., 1947. Some gravels and gravel-pits in Hampshire and Dorset. *Proceedings of the Geologists' Association* **58**, pp. 128 – 143.

Green, J.F.N., 1950. A tour of the terraces of the Avon and Stour. *Proceedings of the Bournemouth Natural Science Society* **39**, pp. 52 – 59.

Grün, R., Schwarz, HP. 2000. Revised open system U-series/ESR age calculations for teeth from Stratum C at the Hoxnian Interglacial type locality, England. *Quaternary Science Reviews* **19**, pp. 1151 – 1154.

Gupta, S., Collier, J.S., Palmer-Felgate, A., Potter, G. 2007. Catastrophic flooding origin of shell valley systems in the English Channel. *Nature* **448**, pp. 342 – 345.

Hamblin, R.J.O., Crosby, A., Balson, P.S., Jones, S.M., Chadwick, R.A., Penn, I.E., Arthur, M.J. 1992. The Geology of the English Channel. British Geological Survey United Kingdom Offshore Regional Report. HMSO: London. 106 pp.

Harding, P., Bridgland, D.R., Allen, P., Bradley, P., Grant, M.J., Peat, D., Schwenninger, J-L., Scott, R., Westaway, R., White, T.S. 2012. Chronology of the Lower and Middle Palaeolithic in NW Europe: developer-funded investigations at Dunbridge, Hampshire, southern England. *Proceedings of the Geologists' Association*

Hatch, M. 2011. Recent fieldwork in the Warsash (Southampton) area: a report on the terrace stratigraphy alongside new optically stimulated luminescence dating. Abstract from: First Workshop of AHOB3 (Ancient Human Occupation of Britain). Dispersal of Early Humans: adaptations, frontiers and new territories. Available from: http://www.ahobproject.org/Publications.php

Hey, R.D. 1979. Dynamic process-response model of river channel development. *Earth Surface Processes* **4**, pp. 59 – 72.

Hijma, M.P., Cohen, K.M., Roebroeks, W., Westerhoff, W.E., Busschers, F.S. 2012. Pleistocene Rhine–Thames landscapes: geological background for hominin occupation of the southern North Sea region. *Journal of Quaternary Science* **27**(1), pp. 17 – 39.

Hopson, P.M. 2001. Geology of the Fareham and Portsmouth district – a brief explanation of the geological map. *Sheet Explanation of the British Geological Survey*, 1:50,000 Sheets 316 and 331 Fareham and Portsmouth (England and Wales).

Hopson, P.M. 2009.The geological setting of the coastal fringes of West Sussex, Hampshire and the Isle of Wight. In *The Quaternary of the Solent Basin and West Sussex Raised Beaches: Field Guide*, Briant, R.M., Bates, M.R., Hosfield, R.T., Wenban-Smith, F.F. (eds). Quaternary Research Association: London, pp. 1 – 20.

Hosfield, R.T. 1999. *The Palaeolithic of the Hampshire Basin: A Regional Model of Hominid Behaviour during the Middle Pleistocene.* BAR British Series 286, Archaeopress: Oxford.

Hosfield, R.T. 2001. The Lower Palaeolithic of the Solent: 'site' formation and interpretive frameworks. In *Palaeolithic Archaeology of the Solent River*, Wenban-Smith, F.F., Hosfield, R.T. (eds). Occasional Paper 7, Lithic Studies Society: Southampton, pp. 85 – 97.

Hosfield, R.T., Wenban-Smith, F.F., Grant, M.J. 2009. Palaeolithic and Mesolithic Archaeology of the Solent Basin and western Sussex region. In *The Quaternary of the Solent Basin and West Sussex Raised Beaches: Field Guide*, Briant, R.M., Bates, M.R., Hosfield, R.T., Wenban-Smith, F.F. (eds). Quaternary Research Association: London, pp.42 – 59.

Hosfield, R. 2011. The British Lower Palaeolithic of the early Middle Pleistocene. *Quaternary Science Reviews* **30**, pp. 1486 – 1510.

Hosfield, R.T., Wenban-Smith, F. F., Grant, M.J. 2009. Palaeolithic and Mesolithic Archaeology of the Solent Basin and and western Sussex region. In *The Quaternary of the Solent Basin and West Sussex Raised Beaches: Field Guide*, Briant, R.M., Bates, M.R., Hosfield, R.T., Wenban-Smith, F.F. (eds). Quaternary Research Association: London, pp. 42 – 59.

Howard, A.J., Brown, A.G., Carey, C.J., Challis, K., Cooper, L.P., Kincey, M., Toms, P. 2007. Archaeological resource modelling in temperate river valleys: a case study from the Trent Valley, UK. *Antiquity* **82**, pp. 1040 – 1054.

Howell, F.C. 1960. European and northwest African Middle Pleistocene hominids. *Current Anthropology* **1**, pp. 195 – 232.

Imai, T., Sakayama, T., Kanemori, T. 1987. Use of Ground-Probing Radar and Resistivity Surveys for Archaeological Investigations. *Geophysics* **52**, pp. 137 – 150.

Kasse, C., 1998. Depositional model for cold-climate tundra rivers. In *Palaeohydrology and Environmental Change*, Benito, G., Baker, V.R., Gregory, K.J. (eds.). Wiley: Chichester, pp. 83 – 97.

Kerney, M.P. 1971. Interglacial deposits at Barnfield Pit, Swanscombe, and their molluscan fauna. *Journal of the Geological Society of London* **127**, pp. 69 – p 93.

Krause, J., Fu, Q., Good, J.M., Viola, B., Shunkov, M.V., Derevianko, A.P., and Pääbo, S. 2010. The complete mitochondrial DNA genome of an unknown hominin from southern Siberia. *Nature* **464**, pp. 894 – 897.

Kubala, M. 1980. The Sand and Gravel Resources of the Country around Fordingbridge, Hampshire. Description of 1:25,000 Sheets SU 11 and Parts of SU 00, 01, 10, 20 and 21. *Institute of Geological Sciences Mineral Assessment Report 50*. HMSO: London.

Lagarde, J.L., Amorese, D., Font, M., Laville, E., Dugué, O. 2003. The structural evolution of the English Channel area. *Journal of Quaternary Science* **18** (3-4), pp. 201 – 213.

Lake, R.D., Mathers, S.J., Thornton, M.H., Zalasiewicz, J.A. 1985. *Geological report on 1:10,000 sheets SU40NE, SE; SU50NW, NE; SU52SW; SU51NW, NE, SW, SE; SU52SW; SU60NW, SW; SU 61SW; SZ59NE and SZ69NW (The south-east Hampshire district: Fareham and surrounding areas).* British Geological Survey: Keyworth, Nottinghamshire.

Lane, E.W., 1955. The importance of fluvial morphology in hydraulic engineering. *Proceedings of ASCE, Journal of Hydrological Division* **81** (745), pp. 1 – 17.

Lang, S.C., Fielding, C.R. 1991. Facies architecture of a Devonian soft-sediment-deformed alluvial sequence, Broken River Province, northeastern Australia. In *The Three-dimensional Facies Architect of Terrigenous Clastic Sediments and its Implications for Hydrocarbon Discovery and Recovery*, Miall, A.D. and Tyler, N. (eds). Society of Economic Paleontologists and Mineralogists, Concepts in Sedimentology and Paleontology Vol. 3, pp. 122 – 132.

Laurent, M., Falguères, C., Bahain, J.J., Rousseau, L., Van Vliet Lanoe, B. 1998. ESR dating of quartz extracted from quaternary and neogene sediments:method, potential and limits. *Quaternary Science Reviews* **17**, pp. 1057 – 1062.

Lee, J.R., Rose, J., Hamblin, R.J.O., Moorlock, B.S.P. 2004. Dating the earliest lowland glaciation of eastern England: the pre-Anglian early Middle Pleistocene Happisburgh Glaciation. *Quaternary Science Reviews* **23**, pp. 1551 – 1566.

Leopold, L.B., Bull, W.B. 1979. Base level, aggradation, and grade. Proceedings of the American Philosophical Society 123, No 2, pp. 168 – 202.

Leopold, L.B., Wolman, M.G., Miller, J.P. 1964. *Fluvial Processes in Geomorphology*. Freeman: San Francisco.

Lewin, J., Gibbard, P.L. 2010. Quaternary river terraces in England: forms, sediments and processes. *Geomorphology* **120**, pp. 293 – 311.

Lewis, S.G., Maddy, D. 1999. Description and analysis of Quaternary fluvial sediments: a case study from the upper River Thames, UK. In *The Description and Analysis of Quaternary Stratigraphic Field Sections*. Jones, A.P., Tucker, M.E., Hart, J.K. (eds). *Technical Guide 7*. Quaternary Research Association: London.

Lewis, S.G, Maddy, D., Scaife, R.G. 2001. Fluvial system response to abrupt climate change during the last Cold Stage: the Upper Pleistocene River Thames fluvial succession at Ashton Keynes, UK. *Global and Planetary Change* **28**, pp. 341 – 359.

Lewis, S.G., Maddy, D., Buckingham, C., Coope, G.R., Field, M.H., Keen, D.H., Pike, A.W.G., Roe, D.R., Scaife, R.G., Scott, K. 2006. Pleistocene fluvial sediments of the upper River Thames at Latton, Wiltshire, England. *Journal of Quaternary Science* **21**, pp. 181 – 205.

Lisiecki, L.E., Raymo, M.E. 2005. A Plio-Pleistocene stack of 57 globally distributed benthic δ18O records. *Paleoceanography* **20**, PA1003. doi:10.1029/2004PA001071.

Lister, A.M. 1992. Mammalian Fossils and Quaternary Biostratigraphy. *Quaternary Science Reviews* **11**, pp. 329 – 344.

Maddy, D. 1997. Uplift-driven valley incision and river terrace formation in southern England. *Journal of Quaternary Science* **12**, pp. 539 – 545.

Maddy, D., Bridgland, D.R. 2000. Accelerated uplift resulting from Anglian glacioeustatic rebound in the Middle Thames Valley, UK?: evidence from the river terrace record. *Quaternary Science Reviews* **19**, pp. 1581 – 1588.

Maddy, D., Lewis, S.G., Bowen, D.Q., Coope, G.R., Green, C.P., Hardaker, T., Keen, D.H., Rees-Jones, J., Parfitt, S., Scott, K. 1998. The Upper Pleistocene deposits at Cassington, near Oxford, England. *Journal of Quaternary Science* **13**, pp. 205 – 231.

Maddy, D., Bridgland, D.R., Green, C.P. 2000. Crustal uplift in southern England: evidence from the river terrace records. *Geomorphology* **33**, pp. 167 – 181.

Mathers, S.J. 1982a. The Sand and Gravel Resources of the Country between Dorchester and Wareham, Dorset. Description of parts of 1:25,000 Sheets SY 68, 69, 78, 79, 88, 89, 98 and 99. *Institute of Geological Sciences Mineral Assessment Report 103*. HMSO: London.

Mathers, S.J. 1982b. The Sand and Gravel Resources of the Country around Lymington and Beaulieu, Hampshire. Description of parts of 1:25,000 Sheets SU 20, 30 and 40 and SZ 29, 39 and 49. *Institute of Geological Sciences Mineral Assessment Report 122*. HMSO: London.

Mauz, B., Lang, A. 2004. Removal of the feldspar-derived luminescence component from polymineral fine silt samples for optical dating applications: evaluation of chemical treatment protocols and quality control procedures. *Ancient TL* **22**, pp. 1 – 8.

McGregor, D.F.M., Green, C.P. 1983a. Post-depositional modification of Pleistocene terraces of the River Thames. *Boreas* **12** (1), pp. 23 – 33.

McGregor, D.F.M., Green, C.P. 1983b. Lithostratigraphic subdivisions in the gravels of the proto-Thames between Hemel Hempstead and Watford. *Proceedings of the Geologists' Association* **94**, pp. 83 – 85.

McGregor, D.F.M., Green, C.P. 1986. Early and Middle Pleistocene gravel deposits of the Thames - development of a lithostratigraphic model. In *Clast Lithological Analysis: Technical Guide 3*, Bridgland, D.R. (ed). Quaternary Research Association, 3, pp. 95-115.

Mejdahl, V. 1985. Thermoluminescence dating of partially bleached sediments. *Nuclear Tracks and Radiation Measurements* **10**, pp. 711 – 715.

Miall, A.D. 1977. A review of the braided river depositional environment. *Earth Science Reviews* **13**, pp. 1 – 62.

Miall, A.D. 1988. Architectural elements and bounding surfaces in fluvial deposits: anatomy of the Kayenta Formation (Lower Jurassic), southwest Colorado. *Sedimentary Geology* **55**, pp. 233 – 262.

Miall, A.D. 1996. The Geology of Fluvial Deposits. Springer: Berlin.

Mol, J., Vandenberghe, J., Kasse, C. 2000. River response to variations of periglacial climate. *Geomorphology* **33**, pp. 131 – 148.

Morwood, M.J., Soejono, R.P., Roberts, R.G., Sutikna, T., Turney, C.S.M., Westaway, K.E., Rink, W.J., Zhao, J.- x., van den Bergh, G. D., Rokus Awe Due, Hobbs, D. R., Moore, M. W., Bird, M. I., and Fifield, L. K. 2004. Archaeology and age of a new hominin from Flores in eastern Indonesia. *Nature* **431**, pp. 1087 – 1091.

Mosquera, M., A. Ollé, A., Rodríguez, X.P. 2013. From Atapuerca to Europe: Tracing the earliest peopling of Europe. *Quaternary International* **295**, pp. 130 – 137.

Muñoz, A., Ramos, A., Sánchez-Moya, Y., Sopeña, A. 1992. Evolving fluvial architecture during a marine transgression: Upper Buntsandstein, Triassic, central Spain. *Sedimentary Geology* **75**, pp. 257 – 281.

Murray, A.S., Wintle, A.G. 2000. Luminescence dating of quartz using an improved single aliquot regenerative-dose protocol. *Radiation Measurements* **33**, pp. 57 – 73.

Murray, A.S., Wintle, A.G. 2003. The single aliquot regenerative dose protocol: potential for improvements in reliability. *Radiation Measurements* **37**, pp. 377 – 381.

Murray, A.S., Olley, J.M., Caitcheon, G.G. 1995. Measurement of equivalent doses in quartz from contemporary water-lain sediments using optically stimulated luminescence. *Quaternary Science Reviews* **14**, pp. 365 – 371.

Muttoni, G., Scardia, G., Kent, D.V., Morsiani, E., Tremolada, F., Cremaschi, M., Peretto, C. 2011. First dated human occupation of Italy at ~0.85 Ma during the late Early Pleistocene climate transition. *Earth and Planetary Science Letters* **307**, pp. 241 – 252.

Neal, A. 2004. Ground-penetrating radar and its use in sedimentology: principles, problems and progress. *Earth-Science Reviews* **66**, pp. 261 – 330.

Nobes, D.C., Ferguson, R.J., Brierley, G.J. 2001. Ground-penetrating radar and sedimentological analysis of Holocene floodplains: insight from the Tuross valley, New South Wales. *Australian Journal of Earth Sciences* **48**, pp. 347 – 355.

Olhoeft, G.R. 1981. Electrical properties of rocks. In *Physical Properties of Rocks and Minerals,* Touloukian, Y.S., Judd, W.R., Roy, R.F. (eds.). McGraw-Hill: New York, pp. 257 – 330.

Olhoeft, G.R. 1998. Electrical, magnetic, and geometric properties that determine ground penetrating radar performance. *Proceedings of GPR'98, Seventh International Conference on Ground Penetrating Radar*. University of Kansas: Lawrence, KS, pp. 177 – 182.

Olhoeft, G.R. 2000. Maximising the information return from ground penetrating radar. *Journal of Applied Geophysics* **43**, pp. 175 – 187.

Olley, J.M., Murray, A., Roberts, R.G. 1996. The effects of disequilibria in the uranium and thorium decay chains on burial dose rates in fluvial sediment. *Quaternary Science Reviews* (*Quaternary Geochronology)* **15**, pp. 751 – 760.

Olley, J., Caitcheon, G., Murray, A. 1998. The distribution of apparent dose as determined by optically stimulated luminescence in small aliquots of fluvial quartz: implications for dating young sediments. *Quaternary Science Reviews* (*Quaternary Geochronology)* **17**, pp. 1033 – 1040.

Oms, O., Parés, J.M., Martínez-Navarro, B., Agustí, J., Toro, I., Martínez-Fernández, G., Turq, A. 2000. Early human occupation of Western Europe: Paleomagnetic dates for two Paleolithic sites in Spain. *Proceedings of the National Academy of Sciences* **97**, pp. 10666 – 10670.

Parfitt, S.A., Barendregt, R.W., Breda, M., Candy, I., Collins, M.J., Coope, G.R., Durbidge, P., Field, M.H., Lee, J.R., Lister, A.M., Mutch, R., Penkman, K.E.H., Preece, R.C., Rose, J., Stringer, C.B., Symmons, R., Whittaker, J.E., Wymer, J.J., Stuart, A.J. 2005. The earliest record of human activity in Northern Europe. *Nature* **438**, pp. 1008 – 1012.

Parfitt, S.A., Ashton, N.M., Lewis, S.G., Abel, R., Coope, G.R., Field, M.H., Gale, R., Hoare, P.G., Larkin, N.R., Lewis, M.D., Karloukovski, V., Maher, B.A., Peglar, S.M., Preece, R.C., Whittaker, J.E., Stringer, C.B. 2010. Early Pleistocene human occupation at the edge of the boreal zone in northern Europe. *Nature* **466**, pp. 229 – 233.

Parrenin, F., Barnola, J.-M., Beer, J., Blunier, T., Castellano, E., Chapellaz, J., Dreyfus, G., Fischer, H., Fujita, S., Jouzel, J., Kawamura, K., Lemieux-Dudon, B., Loulergue, L., Masson-Delmotte, V., Narcisi, B., Petit, J.-R., Raisbeck, G., Raynaud, D., Ruth, U., Schwander, J., Severi, M., Spanhi, R., Steffensen, J.P., Svensson, A., Udisti, R., Waelbroeck, C., Wolff, E. 2007. The EDC3 chronology for the EPICA Dome C ice core. *Climate of the Past* **3**, pp. 485 – 497.

Penkman, K.E.H., Preece, R.C., Keen, D.H., Maddy, D., Schreve, D.C., Collins, M.J. 2007. Testing the aminostratigraphy of fluvial archives: the evidence from intra-crystalline proteins within freshwater shells. *Quaternary Science Reviews* **26**, pp. 2958 – 2969.

Penkman, K.E.H., Kaufman, D.S., Maddy, D., Collins, M.J. 2008. Closed system behaviour of the intra-crystalline fraction of amino acids in mollusc shells. *Quaternary Geochronology* **3**, pp. 2 – 25.

Powers, M.H. 1997. Modeling frequency-dependent GPR. *The Leading Edge* **16**, pp. 1657 – 1662.

Preece, R.C., 2001. Molluscan evidence for differentiation of interglacials within the ‘Cromerian Complex’. *Quaternary Science Reviews* **20**, pp. 1643 – 1656.

Preece, R.C., Scourse, J.D., Houghton, S.D., Knudsen, K.L., Penney, D.N. 1990. The Pleistocene sea-level and neotectonic history of the eastern Solent. *Philosophical Transactions of the Royal Society of London, Series B* **328**, pp. 425 – 477.

Preece, R.C., Parfitt, S.A., Coope, G.R., Penkman, K.E.H., Ponel, P., Whittaker, J.E. 2009. Biostratigraphic and aminostratigraphic constraints on the age of the Middle Pleistocene glacial succession in north Norfolk, UK. *Journal of Quaternary Science* **24**, pp. 557 – 580.

Prescott, J.R. and Hutton, J.T. 1994. Cosmic ray contributions to dose rates for luminescence and ESR dating: large depths and long term variations. *Radiation Measurements* **23**, pp. 497 – 500.

Preusser, F., Degering, D., Fuchs, M., Hilgers, A., Kadreit, A., Klasen, N., Krbetschek, M., Richter, D., Spencer, J.Q.G. 2008. Luminescence dating: basics, methods and applications. *Eiszeitalter und Gegenwart Quaternary Science Journal* **57/1–2**, pp. 95 – 149.

Reid, C., 1893. A fossiliferous Pleistocene deposit at Stone, on the Hampshire coast. *Quarterly Journal of the Geological Society of London* **49**, pp. 325 – 329.

Reid, C. 1898. The geology of the country around Bournemouth. *Memoir, Geological Survey of England and Wales*.

Reid, C. 1899. Geology of the country around Dorchester. *Memoir, Geological Survey of England and Wales*.

Reid, C. 1902a. The geology of the country around Ringwood. *Memoir, Geological Survey of England and Wales*.

Reid, C. 1902b. The geology of the country around Southampton. *Memoir, Geological Survey of England and Wales*.

Regli, C., Huggenberger, P., Rauber, M. 2002. Interpretation of drill core and georadar data of coarse gravel deposits. *Journal of Hydrology*. **255**, pp. 234 – 252.

Reynolds, J.M. 1997. *An Introduction to Applied and Environmental Geophysics*. Wiley: Chichester.

Rhodes, E.J., 2000. Observations of thermal transfer OSL signals in glacigenic quartz. *Radiation Measurements* **35**, pp. 595 – 602.

Rhodes, E.J. Pownall, L. 1994. Zeroing of the OSL signal in quartz from young glaciofluvial sediments. *Radiation Measurements* **23**, pp. 581 – 585.

Rhodes, E.J. & Bailey, R.M. 1997. The effect of thermal transfer on the zeroing of quartz from recent glaciofluvial sediments. *Quaternary Science Reviews* **16**, pp. 291 – 298.

Rightmire, G.P. 1998. Human Evolution in the Middle Pleistocene: The Role of *Homo heidelbergensis*. *Evolutionary Anthropology* **6**, pp. 218 – 227.

Roberts, M.B., Parfitt, S.A. 1999. *Boxgrove: A Middle Pleistocene Hominid Site at Eartham Quarry, Boxgrove, West Sussex*. English Heritage: London.

Robinson, E.S., Çoruh, C., 1988. Basic Exploration Geophysics. Wiley: Chichester.

Roe, D.A. 1968. British Lower and Middle Palaeolithic handaxe groups. *Proceedings of the Prehistoric Society* **34**, pp. 1 – 82.

Roe, H.M. 2001. The late Middle Pleistocene biostratigraphy of the Thames Valley, England: new data from eastern Essex. *Quaternary Science Reviews* **20**, pp. 1603 – 1619.

Roebroeks, W. 2001. Hominid behaviour and the earliest occupation of Europe: an exploration. *Journal of Human Evolution* **41**, pp. 437 – 461.

Roebroeks, W. 2006. The human colonisation of Europe. Where are we? *Journal of Quaternary Science* **21**, pp. 425 – 435.

Roebroeks, W., Conard, N.J., van Kolfschoten, T. 1992. Dense forests, cold steppes and the Paleolithic settlement of northern Europe. *Current Anthropology* **33**, pp. 551 – 567.

Rohling, E.J., Grant, K., Bolshaw, M., Roberts, A.P., Siddall, M., Hemleben, Ch., Kucera, M. 2009. Antarctic temperature and global sea level closely coupled over the past five glacial cycles. *Nature Geoscience* **2**, pp. 500 – 504.

Rohling, E.J., Braun, K., Grant, K., Kucera, M., Roberts, A.P., Siddall, M., Trommer, G. 2010. Comparison between Holocene and Marine Isotope Stage-11 sea-level histories. *Earth and Planetary Science Letters* **291**, pp. 97 – 105.

Rose, J., 1995. Lateglacial and early Holocene river activity in lowland Britain. In *European River Activity and Climatic Change during the Lateglacial and Early Holocene*, Frenzel, B., Vandenberghe, J., Kasse, C., Bohncke, S., Glaser, B. (eds.). *Paläoklimaforschung* **14**, pp 51 – 74.

Rose, J. 2006. A perspective on D. R. Bridgland's paper 'The Middle and Upper Pleistocene sequence in the Lower Thames: a record of Milankovitch climatic fluctuation and early human occupation of southern Britain'. *Proceedings of the Geologists' Association* **117**, pp. 277 – 279.

Rose, J. 2009. Early and Middle Pleistocene landscapes of eastern England. *Proceedings of the Geologists' Association* **120**, pp. 3 – 33.

Rose, J. 2010a. The Quaternary of the British Isles: factors forcing environmental change. *Journal of Quaternary Science* **25** (4), pp. 399 – 418.

Rose, J. 2010b. Quaternary climates: a perspective for global warming. *Proceedings of the Geologists' Association* **121**, pp. 334 – 341.

Rowe, P.J., Richards, D.A., Atkinson, T.C., Bottrell, S.H., Cliff, R.A. 1997. Geochemistry and radiometric dating of a Middle Pleistocene peat. *Geochemica et Cosmochimica Acta* **61**, pp. 4201 – 4211.

Rowe, P.J., Atkinson, T.C., Turner, C. 1999. U-series dating of Hoxnian interglacial deposits at Marks Tey, Essex, England. *Journal of Quaternary Science* **14**, pp. 693 – 702.

Schreve, D.C. 2001a. Mammalian evidence from fluvial sequences for complex environmental change at the oxygen isotope substage level. *Quaternary International* **79**, pp. 65 – 74.

Schreve, D.C. 2001b. Differentiation of the British late Middle Pleistocene interglacials: the evidence from mammalian biostratigraphy. *Quaternary Science Reviews* **20**, pp.1693 – 1705.

Schumm, S.A. 1977. *The Fluvial System*. Wiley-Interscience: New York, 338 pp.

Schumm, S. 1979. Geomorphic thresholds: the concept and its applications. *Transactions Institute British Geographers,* NS **4**, pp. 485 – 515.

Schwenninger, J.-L., Rhodes, E.J., Bates, M.R., Briant, R.M., Wenban-Smith, F.F. 2006. *Optically Stimulated Luminescence (OSL) Dating of Quaternary Deposits from the Sussex/Hampshire Coastal Corridor*. English Heritage Research Department Report Series 20/2006.

Schwenninger, J.-L., Bates, M.R., Briant, R.M., Wenban-Smith, F.F. 2007. *Further Optically Stimulated Luminescence (OSL) Dates of Quaternary Deposits from the Sussex/Hampshire Coastal Corridor*. English Heritage Research Department Report Series 55/2007.

Sensors and Software 1998. Technical Manual 29: PulseEKKO Tools. User's Guide v2.0. Sensors and Software, Ontario.

Sensors and Software 1999. Technical Manual 15: PulseEKKO Velocity Analysis. User's Guide v4.2. Sensors and Software, Ontario.

Shackley, M.L., 1970. Preliminary note on handaxes found in gravel deposits at Warsash, Hampshire. *Proceedings of the Hants Field Club Archaeological Society* **27**, pp. 5 – 7.

Skelly, R.L., Bristow, C.S., Ethridge, F.G. 2003. Architecture of channel-belt deposits in an aggrading shallow sandbed braided river: the lower Niobrara River, northeast Nebraska. *Sedimentary Geology* **158**, pp. 249 – 270.

Smith, A.J. 1985. A catastrophic origin for the palaeovalley system of the eastern English Channel. *Marine Geology* **64**, pp. 65 – 75.

Smith, S.A. 1990. The sedimentary and accretionary style of an ancient gravel-bed stream: the Budleigh Salterton Pebble Beds (Lower Triassic), southwest England. *Sedimentary Geology* **67**, pp. 199 – 219.

Smith, D.G., Jol, H.M. 1995. Ground-penetrating radar: antenna frequencies and maximum probable depths of penetration in Quaternary sediments. *Journal of Applied Geophysics* **33**, pp. 93 – 100.

Soegaard, K. 1991. Architectural elements of fan-delta complex in Pennsylvanian Sandia Formation, Taos Trough, Northern New Mexico. In *The Three-dimensional Facies Architect of Terrigenous Clastic Sediments and its Implications for Hydrocarbon Discovery and Recovery*, Miall, A.D. and Tyler, N. (eds). Society of Economic Paleontologists and Mineralogists, Concepts in Sedimentology and Paleontology Vol. 3, pp. 217 – 2223.

Stephens, M. 1994. Architectural element analysis within Kayenta Formation (Lower Jurassic) using ground-probing radar and sedimentological profiling, southwestern Colorado. *Sedimentary Geology* **90**, pp. 179 – 211.

Strahan, A. 1896. On the physical geology of Purbeck. *Proceedings of the Geologists' Association* **14**, pp. 405 – 408.

Sutcliffe, A.J. 1976. Reply to R.G. West on The British Glacial-Interglacial Sequence. *Quaternary Newsletter* **18**, pp. 1 – 7.

Tillard, S., Dubois, J.-C. 1995. Analysis of GPR data: wave propagation velocity determination. *Journal of Applied Geophysics* **33**, pp. 77 – 91.

Toro, I., De Lumley, H., Fajardo, B., Barsky, D., Cauche, D., Celiberti, V., Grégoire, S., Martínez-Navarro, B., Espigares, M.P., Ros-Montoya, S. 2009. L'industrie lithique des gisements du Pléistocène inférieur de Barranco León et Fuente Nueva 3 à Orce, Grenade, Espagne. *L'Anthropologie* **113**, pp. 111 – 124.

Toucanne, S., Zaragosi, S., Bourillet, J.F., Cremer, M., Eynaud, F., Van Vliet-Lanoë, B., Penaud, A., Fontanier, C., Turon, J.L., Cortijo, E., Gibbard, P.L. 2009. Timing of massive 'Fleuve Manche' discharges over the last 350 kyr: insights into the European ice-sheet oscillations and the European drainage network from MIS 10 to 2. *Quaternary Science Reviews* **28**, pp. 1238 – 1256.

Van den Berg, M., 1996. Fluvial sequences of the Maas: a 10Ma record of neotectonics and climatic change at various time-scales. PhD Thesis, LU Wageningen, 180 pp.

Vandenberghe, J. 1993. Changing fluvial processes under changing periglacial conditions. *zeitschrift für geomorphologie*. Supplement Band **88**, pp. 17 – 28.

Vandenberghe. J. 1995. Timescales, climate and river development. *Quaternary Science Reviews* **14**, pp. 631 – 638.

Vandenberghe, J. 2001. A typology of Pleistocene cold-base rivers. *Quaternary International* **79**, pp. 111 – 121.

Vandenberghe, J. 2002. The relation between climate and river processes, landforms and deposits during the Quaternary. *Quaternary International* **91**, pp. 17 – 23.

Vandenberghe, J. 2003. Climate forcing of fluvial system development: an evolution of ideas. *Quaternary Science Reviews* **22**, pp. 2053 – 2060

Vandenberghe, J. 2008. The fluvial cycle at cold–warm–cold transitions in lowland regions: a refinement of theory. *Geomorphology* **98**, pp. 275 – 284.

Vandenberghe, J., van Overmeeren, R.A. 1999. Ground penetrating radar images of selected fluvial deposits in The Netherlands. *Sedimentary Geology* **128**, pp. 245 – 270.

van Overmeeren, R.A. 1998. Radar facies of unconsolidated sediments in The Netherlands: a radar stratigraphy interpretation method for hydrogeology. *Journal of Applied Geophysics* **40**, pp.1 –18.

Vaughn, C.J. 1986. Ground-Penetrating Surveys Used in Archaeological Investigations. *Geophysics* **51**, pp. 595 – 604.

Velegrakis, A.F., Dix, J.K., Collins, M.B. 1999. Late Quaternary evolution of the upper reaches of the Solent River, southern England, based on marine geophysical evidence. *Journal of the Geological Society of London* **156**, pp. 73 – 87.

Walden, J., Oldfield, F., Smith, J. 1999. Environmental magnetism: a practical guide. *QRA Technical Guide*, volume 6. QRA: London.

Wallinga, J. 2002. Optically stimulated luminescence dating of fluvial deposits: a review. *Boreas* **31**, pp. 303 – 322.

Wallinga, J., Murray, A., Wintle, A. 2000. The single-aliquot regenerative-dose (SAR) protocol applied to coarse grain feldspar. *Radiation Measurements* **32**, pp. 529 – 533.

Wenban-Smith, F.F. 2001. As represented by the Solent River: handaxes from Highfield, Southampton. In *Palaeolithic Archaeology of the Solent River*, Wenban-Smith, F.F., Hosfield, R.T. (eds). Occasional Paper 7, Lithic Studies Society: Southampton, pp. 57 – 69.

Wessex Archaeology. 1993. The Southern Rivers Palaeolithic Project. Report No. 1. 1991 – 1992. The Upper Thames Valley, the Kennett Valley and the Upper Solent Drainage System. Wessex Archaeology & English Heritage: Salisbury.

West, R.G., Sparks, B.W. 1960. Coastal interglacial deposits of the English Channel. *Philosophical Transactions of the Royal Society of London, Series B* **243**, pp. 95 – 133.

Westaway, R. 2008. Quaternary vertical crustal motion and drainage evolution in East Anglia and adjoining parts of southern England: chronology of the Ingham River terrace deposits. *Boreas*, Vol. **38**, pp. 261 – 284.

Westaway, R. 2011. A re-evaluation of the timing of the earliest reported human occupation of Britain: the age of the sediments at Happisburgh, eastern England. *Proceedings of the Geologists' Association* **122**, pp. 383 – 396.

Westaway, R., Maddy, D., Bridgland, D.R. 2002. Flow in the lower continental crust as a mechanism for the Quaternary uplift of southeast England: constraints from the Thames terrace record. *Quaternary Science Reviews* **21**, pp. 559 – 603.

Westaway, R., Bridgland, D.R., White, M.J. 2006. The Quaternary uplift history of central southern England: evidence from the terraces of the Solent River system and nearby raised beaches. *Quaternary Science Reviews* **25**, pp. 2212 – 2250.

White, H.J.O. 1912. The geology of the country around Winchester and Stockbridge. *Memoir, Geological Survey of England and Wales*.

White, H.J.O. 1915. The geology of the country near Lymington and Portsmouth. *Memoir, Geological Survey of England and Wales*.

White, H.J.O. 1917. The geology of the country around Bournemouth. *Memoir, Geological Survey of England and Wales*.

White, M.J., Schreve, D.C. 2000. Island Britain-peninsula Britain: palaeogeography, colonisation, and the Lower Palaeolithic settlement of the British Isles. *Proceedings of the Prehistoric Society* **66**, pp. 1 – p 28.

Wintle, A.G. 1973. Anomalous fading of thermoluminescence in mineral samples. *Nature* **245**, pp. 143 – 144.

Wintle, A.G. 1980. Thermo-Luminescence dating – A review of recent application to non-pottery materials. *Archaeometry* **22**, pp. 113 – 122.

Wintle, A.G., Huntley, D.J. 1979. Thermoluminescence dating of a deep-sea sediment core. *Nature* **279**, pp. 710 – 712.

Wintle, A.G. Huntley, D.J. 1980. Thermoluminescence dating of ocean sediments. *Canadian Journal of Earth Sciences* **17**, pp. 348 – 360.

Wintle, A.G., Murray, A.S. 2000. Quartz OSL: effects of thermal treatment and their relevance to laboratory dating procedures. *Radiation Measurements* **32**, pp. 387 – 400.

Wintle, A.G., Murray, A.S. 2006. A review of quartz stimulated luminescence characteristics and their relevance in single-aliquot regeneration dating protocols. *Radiation Measurements* **41**, pp. 369 – 391.

Wizevich, M.C. 1992. Sedimentology of Pennsylvanian quartzose sandstones of the Lee Formation, central Appalachian Basin: fluvial interpretation based on lateral profile analysis. *Sedimentary Geology* **78**, pp. 1 – 47.

Wymer, J.J. 1968. *Lower Palaeolithic archaeology in Britain as represented by the Thames Valley*. John Baker: London.

Wymer, J.J. 1999. *The Lower Palaeolithic occupation of Britain.* 2 volumes. Wessex Archaeology and English Heritage: Salisbury.

Zeuner, F.W. 1945. *The Pleistocene Period: its Climate, Chronology and Faunal Successions* 1st edition. Ray Society Publications **130**.